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A SURVEY OF THERMAL POWER PLANT COOLING FACILITIES. (REPORT ON TRIP TO SEVEN THERMAL POWER PLANTS, DECEMBER 1968)

Robert W. Zeller, et al

Pollution Control Council
Portland, Oregon

April 1969

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a survey of

THERMAL POWER PLANT COOLING FACILITIES

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41

A SURVEY OF THERMAL

POWER PLANT COOLING FACILITIES

REPORT ON TRIP TO SEVEN

THERMAL POWER PLANTS

DECEMBER 1968

by

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Details of illustrations in
this document may be better
studied on microfiche

April 1969

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CONTENTS

Chapter		Page
I.	INTRODUCTION	1
II.	POWER PLANT TOUR	5
	Keystone Generating Station	7
	Mt. Storm Mine-Mouth Power Station	13
	Ft. Martin Power Station	19
	Clinch River Plant	23
	Big Sandy Plant	29
	Alamitos Steam Station	33
	San Onofre Nuclear Generating Station	39
III.	CONCLUSIONS	45
	Power Plants Visited During the Tour	45
	Potential Power Plant Sites in the Northwest	51
APPENDICES		55
	A. Illustrations	
	B. Power Plant Data	

I. INTRODUCTION

The Northwest Pollution Control Council passed a resolution in November 1968 requesting increased interagency attention to environmental aspects of thermal power plant siting in the Northwest. Specifically, it was suggested that an interagency tour of thermal power plants be organized and conducted as soon as possible. The Northwest Regional Office, FWPCA, accepted the responsibility for making the necessary arrangements, and a tour of seven power plants was completed in December 1968. Included were five coal-fired plants in eastern United States, one gas/oil plant at Long Beach, California, and a nuclear power plant near San Clemente, California.

Participants in the tour included Dr. Robert Zeller and Mr. Herbert Simison, FWPCA; Messrs. E. Jack Weathersbee and Harold Patterson, Oregon State Sanitary Authority, Portland; Mr. George Hansen, Washington Water Pollution Control Commission, Olympia; and Mr. Peter Hildebrandt, Washington Office of Air Quality Control, Seattle. Local tour arrangements were made through Mr. R. A. Vanderhoof, Director, Ohio Basin Region, FWPCA, and Mr. Paul DeFalco, Director, Southwest Region, FWPCA.

Since the general purpose of the power plant visits was to personally observe the impact of various cooling methods on air and water quality, these characteristics are emphasized in the several specific objectives as follows:

(1) To gain "first-hand" impressions of environmental aspects of natural draft and forced draft cooling towers, cooling ponds, and ocean outfalls.

(2) To elicit answers and generate discussion from plant personnel on cooling facility performance characteristics, impact on air and water quality, and public acceptance.

(3) To locate sources for additional field data on thermal power plant environmental characteristics.

(4) To obtain information for translating the environmental characteristics which we observed to potential power plant locations in the Northwest.

The following pages document our observations and discussions on each of the power plants visited. Included in Appendix A are 17 photographs taken by Mr. Simison during the tour and two maps. The discussion of each power plant is prefaced by a paragraph on plant location, ownership, type, size, source of cooling water, and method for treating cooling water. A more complete list of plant specifications will be found in Appendix B at the end of the report.

To fully appreciate the commentary in the report, it is important to realize that all five thermal power plants visited in eastern United States are mine-mouth generating stations. Figure 1 in Appendix A shows the locations of the power plants visited relative to cities of over 100,000 population. These generating stations were built close to the coal mines in relatively remote locations, because recent technological advances have made it cheaper to transmit high

voltage power to the "load centers" than it is to ship coal. However, surface water supplies at all five locations are inadequate to supply the tremendous cooling water requirements of the power plant condensers on a once-through basis. Consequently, cooling towers at four locations and a cooling pond at the fifth, were incorporated into the design of these power plants to conserve on water supplies.

It is also important to note that the data given on performance characteristics at the several power plants were transcribed from notes taken during our discussions with plant personnel and are, therefore, "second-hand." No large discrepancies in the notes were evident, however.

II. POWER PLANT TOUR

Final arrangements for the tour were reviewed at the office of Mr. R. A. Vanderhoof, Director, Ohio Basin Region, FWPCA, Cincinnati, Ohio. Although most of the arrangements for the tour of eastern power plants were made by Dr. F. A. Rohrman, Special Assistant to Mr. Vanderhoof, he was unable to participate in the trip with us. Mr. Vanderhoof accompanied us, however, as we began our tour on Monday afternoon, December 16, 1968.

KEYSTONE GENERATING STATION, SHELOCTA, PA.

Location: Near Shelocta, Pa., on the Indiana-Armstrong county line.

Owner: Multiple (investor-owned utilities).

Type: Coal-fired (mine-mouth).

Capacity: 1800 MW from 2 units.

Condenser Cooling Water Requirement: 560,000 gpm.

Plant "Makeup Water" Requirement and Source: 8,500 to 15,500 gpm from Crooked Creek downstream of a 25,000 AF reservoir on the North Branch of Plum Creek.

Waste Heat Treatment: 4 Hamon-Cottrell, hyperbolic cooling towers of the counter-current flow pattern type.

We were met by Mr. Frank Schiermier at Indiana, Pa., who acted as our local contact for the Keystone Generating Station visit. Mr. Schiermier is on loan from ESSA to USPHS, Air Pollution Control, and is stationed at the Jimmy Stewart Airport near Indiana, Pa.

During the drive from his office to Keystone, Mr. Schiermier described a 15-month old study on the characteristics of the power plant stack (chimney) emissions. Under the direction of Mr. Robert McCormick, USPHS, Cincinnati, Ohio, a mathematical model is being developed to describe the rise, shape, and downwind extent of the stack emission plumes. Model predictions will be tested against physical measurements of the plumes taken during regular helicopter

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flights. Measurements taken by helicopter include air temperature (T_a), dewpoint (T_d), altitude, and sulfur dioxide (SO_2) concentrations.

Mr. Schiermier also described the cooling tower plumes. During stable atmospheric conditions of 100 percent relative humidity (RH) and uniform temperatures, the tower plumes may come close to the tops of hills surrounding the power plant. Under all other conditions, the plumes rise satisfactorily. In fact, Mr. Schiermier later described helicopter photographs of the plumes breaking through the tops of fog layers, looking very much like "four fingers" from above.

The weather at Keystone Station was cold and blustery when we arrived at 5:00 pm. (T_a=17^{o}F, RH=72% wind speed (W)=20mph) The sky was heavily overcast. There had been snow showers until 2:00 pm that afternoon. Fig. 2 shows the Keystone Station with its 4 natural draft cooling towers, 2 for each generating unit.

Dense plumes were being emitted from two of the four cooling towers. As seen on Fig. 2, the plumes were extremely turbulent and occasionally looped halfway down to the ground surface. These were the "heaviest" plumes among all the power plants visited. Except for the "turbulent loops," however, the plumes were rising and dissipating.

We were met at the Keystone Station by Mr. Sam McKinney, Plant Manager, and Mr. Dick Killen who spent over an hour with us answering questions.

Mr. McKinney pointed out that only one of the two 900 MW power units was running. The other unit was entering the eleventh week of a scheduled shutdown for maintenance and servicing.

According to Mr. McKinney, the condenser cooling water supplied to the generating station from Crooked Creek below their 25,000 acre foot (AF) reservoir on the North Branch of Plum Creek is of generally good quality. Plum Creek discharges into Crooked Creek above the power plant. Fig. 3 shows the section of Crooked Creek between the reservoir and the Keystone Station in the background.

Lime slurry is added to the condenser cooling water to adjust pH upwards from 6.5 to 7.5. No chemical treatment is required for slime control at this time. Condenser cooling water is withdrawn from the cold water basin under each tower at a rate of 2,500 gpm to be used in transporting fly ash to sedimentation ponds. The overflow from these sedimentation ponds goes to a lagoon for pH adjustment and then into Crooked Creek downstream of the plant. Utilizing a part of the cooling tower effluent in this fashion precludes the need for separate "blowdown" facilities to avoid a buildup of dissolved solids in the recirculated cooling water. (Since the loss of water by evaporation in the towers tends to concentrate dissolved solids in the recirculated cooling water, a part of this water is exchanged for fresh water to control the buildup of dissolved solids. This exchange process is referred to as tower blowdown.)

The natural draft cooling towers at Keystone were selected over mechanical draft towers on the basis of their lower operation and maintenance costs. Mr. McKinney stated that the use of upstream reservoir storage and cooling towers has made the Keystone Station

economical, because it was cheaper to locate the plant near the coal resource and build towers than to locate near the "load center" and pay extra fuel transportation costs. It was noted that there is insufficient water at Keystone for once-through cooling.

During the summer months, (T_a=72°F., RH=50%) the Keystone cooling towers are designed to lower the cooling water temperatures from a probable maximum of 118°F down to 90°F. This designed temperature reduction in the tower is called the "operating range" for the given weather conditions and warm water temperature. The design operating range in the winter is from 90° down to about 60°F. It was noted that condenser efficiencies at Keystone decline when the tower effluent (cold water) temperatures rise above 72°F, but will continue to operate up to a maximum cold water temperature of 95°F. This is 5°F higher than the probable maximum cold water temperature of 90°F given above. Of course, the reduced condenser efficiencies at high temperatures cost the power company money in terms of reduced power production.

Performance of the towers has been tested by plant personnel under the supervision of Research Cottrell of which Hamon Cottrell is a subsidiary. Two series of tests were conducted (1) during the relatively cold fall/spring weather conditions and (2) during mid-summer conditions. The towers performed better than guarantee specifications in these tests. It was noted, however, that these towers were slightly "oversized" to be sure of their performance. Cooling water evaporation

to the atmosphere from the towers has averaged 6,000 to 7,000 gpm and 12,000 to 13,000 gpm during the winter and summer respectively.

Operation and maintenance costs of the Keystone cooling towers are minimal. Icing of the tower can occur in very cold weather, but is alleviated by concentrating the warm water flow in half of the tower. This technique reduces tower efficiency somewhat, although it effectively discourages ice formation. Since the towers are not "operated" in a physical sense, measurement of atmospheric conditions is not essential. Although air temperatures and wet bulb temperatures are recorded, instrumental difficulties have prevented continuous records of the wet bulb readings.

Impact of the Keystone Station on water quantity and quality has been beneficial. Crooked Creek minimum flows downstream have been increased from less than 5.0 cfs to 30 cfs. Because of acid mine drainage, the preconstruction pH of Crooked Creek averaged about 2.5. This has been raised to 6.5 or better by return water from the plant and releases from the Plum Creek reservoir.

The impact of cooling tower operation on local weather conditions was discussed in detail. Mr. McKinney stated that the tower plumes never reach the ground, not even on the surrounding hills. Plume density and size are most noticeable during muggy, "almost raining" weather, but reportedly do not cause or contribute to local fogging conditions. When relative humidities are low, the plumes are almost invisible.

No carryover of water droplets from the top of the towers has been evident under normal operating conditions because of "drift eliminators" above the tower fill. (Drift eliminators are vanes which change the angle of the saturated air stream enough to cause entrained droplets of water to fall back into the base of the tower.) They do, however, occasionally get some spray when ground level winds of 30 to 40 mph carry water droplets through the towers.

Although the stack (chimney) emission and tower plumes intermingle at times, there have been no verified reports of "acid misting". The Keystone plant is located in the middle of Christmas tree country, but there have been no complaints of damage. There has been an assortment of complaints, however, by individuals involving some damage to other vegetation. The U. S. Public Health Service has an imcomplete study of area ground cover to ascertain the presence and source of any vegetation damage. Conclusions have not yet been reached and are complicated by potential damage to vegetation from the common practice of burning mine dumps in that area. Overall, the plant personnel concluded that public acceptance of the Keystone Station has been good.

MT. STORM MINE-MOUTH POWER STATION

Location: On the Stony River near Mt. Storm, W. Va., in Grant County

Owner: Virginia Electric and Power Co. (VEPCO)

Type: Coal-fired (mine-mouth)

Capacity: 1080 MW from 2 units

Condenser Cooling Water Requirement and Source: 500,000 gpm from an adjacent 1200 acre reservoir on the Stony River.

Waste Heat Treatment: None; once-through cooling with reservoir water

We drove down to the Mt. Storm Power Station from Uniontown, Pennsylvania, early on Tuesday morning, December 17. The weather at Mt. Storm located on the Appalachian Ridge (El. 3255), was cold, windy and clear (T_a=20°F, RH=70%, W=25 mph). There had been snow showers during the preceding day.

We approached Mt. Storm from the north side, or lower end of the reservoir on Stony River used as a cooling pond. Fig. 4 shows the Mt. Storm Power Station and a portion of the reservoir forebay. "Steam fog," caused by a cold air mass over the warm water surface, was very evident above the reservoir. There was considerable icing along the shoreline as a result of this steam fog as seen in the foreground of the reservoir on Fig. 4. (Although steam fog occurs naturally, it is not a common phenomenon and should not be confused with the more common generalized fogging conditions which occur

over widespread areas, usually during early morning hours.) The steam fog observed at Mt. Storm was induced by the warm water discharges into the reservoir. In any case, the steam fog was not objectionable and had no observed effect on local weather conditions near the adjacent highway or power station.

We were met at the Mt. Storm Power Station by Mr. N. G. Kirby, Plant Superintendent, Mr. B. J. Peterson, Chief Chemist, VEPCO, Richmond, Virginia, and Mr. J. G. Gardner, FWPCA, Charlottesville. One of the two 560 MW generating units was "out" at the time of our visit. Mr. Kirby explained that the location of the Mt. Storm plant near the mine fields was economically determined by the saving in coal transportation costs over alternative locations nearer the load centers. The problem of insufficient water supplies for once-through cooling or natural draft cooling towers was solved by construction of the reservoir on Stony River adjacent to the power station. In addition, the reservoir has sustained low flows in Stony River adjacent to the power station. In addition, the reservoir has sustained low flows in Stony River with a guaranteed minimum of 2 cfs below the damsite compared with minimum natural flows of 0.4 cfs.

The reservoir is formed by a 1700 foot long dam across Stony River one-half mile downstream from the power station. The 1200 acre reservoir extends 4 miles up Stony River with backwaters also up Laurel Creek and Helmick Run. Reservoir depths are 150 feet near the dam and 25 to 50 feet in each "finger".

There is a spillway at the west end of the dam plus a discharge pipe 20 feet below the surface metered at 2 cfs. According to Mr. Kirby, there is flow over the spillway most of the time in addition to the pipe discharge. Concrete water intake for the power station are located on the reservoir bottom at 90 foot depth alongside the plant. Travelling screens with 3/8-inch mesh, for exclusion of debris, are located on the intake lines at the pumpwell. Pumping capacity for the plant is 250,000 gpm per unit. Twin, 90-inch diameter pipes discharge the heated cooling water from shoreline outfalls at the reservoir surface, one upstream and one downstream of the plant. Fig. 5 shows the shoreline discharge downstream of the power station. The reservoir dam is in the upper left of the photograph.

Water levels in the reservoir are relatively constant with maximum seasonal fluctuations of less than 2 feet.

Water quality of the Stony River before reservoir construction was satisfactory with a normal pH of 6 or better. Stony River was a good trout stream at that time. Acid mine drainage has reduced average pH levels in the reservoir to about 4.2 at the present time, killing most of the resident fish life. However, the stream is stocked with trout about 2 miles downstream where the pH is about 5.9.

Some of the problem with pH levels may have been due to the ash sluice water since there is no lime in the coal supply. The

pH of the ash sluice water is now adjusted upwards to 6.0 with the addition of lime slurry. The quantity of water involved is 1200 gpm.

Reservoir pH levels have stabilized and are not expected to drop much further. The intake water supply is not treated for pH control, since the cooling water conduits are of corrosion resistant stainless steel and epoxy lined concrete. Algacides are not added to the cooling water, although some brown algae were noted in the reservoir during the summer of 1968.

Aside from pH, water quality in the reservoir is fair. Dissolved oxygen levels average 5.0 to 6.5 parts per million (ppm) in the summer months. Dissolved solids average about 30 ppm.

Reservoir water temperatures are moderate and surprisingly uniform. Mr. Kirby stated that maximum water surface temperatures reach 84°F in the summer with less than 2.0°F difference in temperature between water surface and 90 foot (plant intake depth) reaches 3.0 to 3.5°F and the difference down to 150 feet (maximum depth) reaches about 10°F. Vertical temperature gradients are fairly uniform, however, with no apparent thermocline (zone of rapidly changing temperature) development. Consequently, cooling water intake temperatures reach a maximum of 80 to 82°F. With a 20° increase across the condensers, the cooling water discharge temperatures reach 100 to 102°F. These highest temperatures cause some back pressure on the condensers, but efficiency losses are minor.

Water temperatures are not monitored upstream from the power station reservoir. USGS has a thermograph at the Hwy. 50 bridge 2.5 miles downstream on the Stony River. Stream temperatures are near normal there with maximum summer levels of about 65°F.

Personnel from the Mt. Storm Station and VEPCO, Richmond, conducted a temperature survey on the reservoir during the summer of 1968 from which the above data on summer temperatures were obtained. Measurements of reservoir inflows were considered inadequate, however, to permit detailed energy budget calculations for the reservoir or to estimate water surface evaporation rates.

The impact of the power station and reservoir on local weather conditions has been minimal. There is considerable, naturally occuring fog during early morning hours of the winter months in the vicinity of Mt. Storm. Fog conditions have not been aggravated by the reservoir. There have been no complaints on fogging.

VEPCO personnel are pleased with the reservoir performance. Aesthetically, the reservoir is no problem. Recreational boating is provided free to the local residents. Swimming, however, is difficult because of steep banks around the reservoir.

FT. MARTIN POWER STATION

Location: On the Monongahela River just south of the Pennsylvania-West Virginia border, near Point Marion, Pa.

Owner: Alleghany Power System and Duquesne Light Co.

Type: Coal-fired (mine-mouth)

Capacity: 1080 MW from 2 units

Condenser Cooling Water Requirement: 400,000 to 540,000 gpm

Plant Makeup Water Requirement and Source: 10,000 gpm from the Monogahela River.

Waste Heat Treatment: 2 Marley hyperbolic cooling towers of the cross-flow type.

From Mt. Storm, W.Va., we drove to the Ft. Martin Power Station near Point Marion, Pa. The weather was clear and cool with a light breeze (T_a = 35°F, RH = 57%, W = 12 mph). Ft. Martin is located along the Monongahela River with hills on either side. As we approached the power station, we could see a dense plume rising from one tower (Unit 2 was down) and drifting to the southwest. This plume is shown on Fig. 6. The plume was clearly visible for several miles.

We were met by Mr. Don Snyder, assistant plant manager, since Mr. Hackett, plant manager, was out of town. Mr. Snyder and Mr. Kim Vogel answered our questions about the power station and cooling facilities. They explained that Unit 2, although "on commercial" as of Nov. 30, 1968, was still being "debugged" and was temporarily down.

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The cross-flow, natural draft, Marley towers were incorporated in the plant design primarily to avoid expensive pre-treatment of the entire cooling water supply. The base of one tower, with its external "fill" or "packing" is shown on Fig. 7. Acid mine drainage into the Monongahela River has reduced its pH to average levels of 3.0 to 5.5.

Recirculation of cooling tower effluent has reduced plant make-up water requirements from a maximum of over 500,000 gpm to 10,000 gpm. Consequently, the costs of pre-treatment, primarily pH adjustment, have been drastically reduced over that necessary for once-through cooling.

Makeup water requirements include about 7,000 gpm for evaporation losses and 3,000 gpm ash handling loss. Water pumped from the Monongahela River is treated with lime to raise the pH to 6.5 - 7.0 Chlorine is also added once each day as a bactericidal agent.

The 4.7 million gallon (MG) cooled-water reservoirs at the base of each tower are monitored to maintain specific conductivity below 2500 micro mhos. About 3000 gpm are withdrawn from these reservoirs for ash handling. This withdrawal serves as an adequate "blowdown" operation. The ash slurry is pumped to a settling basin from which the overflow returns to the Monongahela. The lime content in the ash raises the pH of this return water to about 10.2.

The impact of Ft. Martin Power Station on Monongahela River water quality would tend to be beneficial, because of the increased pH of the settled ash handling water.

At the time of plant dedication (May 30, 1967 for Unit 1), these towers were the largest natural draft towers in the world, 370 ft. high and 373 ft. across the base. Each tower serves one 540 MW generating unit and is designed for a cooling water flow of 250,000 gpm and a temperature drop of 24°F between inflow and outflow. At flows of 270,000 gpm on one tower, the Marley acceptance tests yielded a temperature drop of 17° under the conditions of the tests. Although outflow temperatures were as expected, the inflow (heated) temperatures were lower than expected. Tentatively, it was concluded that the towers were somewhat "overdesigned" for the plant.

The tower circulation pumps are set up to provide flow to 1/3, 2/3, or the entire tower as desired for icing control. Operating data showed this to have an influence on the cooling efficiency of the towers.

The impact of the station on local weather conditions is reportedly small. The plumes will occasionally "roll" off the lips of the cooling towers, causing external icing problems on the tower, but rise satisfactorily. Under the worst conditions (cool, misty mornings), the plumes will extend several miles downwind, but never drop to the level of the surrounding hills. During dry periods on the other hand, the plumes are almost invisible. There is no apparent contribution to naturally occuring, local fog conditions.

The plant stack emissions and cooling tower plumes will occasionally intermingle, but with no verified complaints of acid misting.

Public acceptance of the cooling towers has been mixed. There have

been unconfirmed complaints related to fogging and problems due to acid misting. Plant operators, however, are convinced that the station has had no adverse effects on air quality.

Note that the Ft. Martin Power Station is about 2 miles from Point Marion, Pa. (pop.=1900), but otherwise remote from population centers.

CLINCH RIVER POWER PLANT, CARBO, VA.

Location: On the Clinch River near Carbo, Virginia in Russell County

Owner: Appalachian Power Company (American Electric Power System)

Type: Coal-fired (mine-mouth)

Capacity: 700 MW from 3 units

Condenser Cooling Water Requirement: 330,000 gpm

Plant "Makeup Water" Requirement and Source: 7500 gpm from the Clinch River.

Waste Heat Treatment: 4 - 10 cell Marley, induced draft, cooling towers

1 - 14 cell Marley, induced draft, cooling tower

We drove up from the TriCity airport near Bristol, Tenn., during the morning and early afternoon of Dec. 18 to the Clinch River Plant near Carbo, Va. It was warm with thin, high cirrus clouds and a light breeze when we arrived at the power plant (T_a=53°F, RH=34%, W=5mph). The stack plumes were observed to be rising straight up and bending to the south. The plumes from all five cooling towers were quite thin and disappeared within 200 ft. from the towers. Fig. 8 shows the Clinch River Power Plant with its twin stacks and mechanical draft towers. Trains are shown in the foreground of Fig. 8.

We passed the plant intake structure on the banks of the Clinch River. There was some icing around the edges, as seen on Fig. 9, but not severe.

Messrs. T. W. Abolin, Plant Manager; Tom Watson, Performance Engineer; and Ray McComis, Chemist, met us in the plant offices for a brief discussion. Messrs. Watson and McComis subsequently conducted us on a tour of the power plant and cooling towers.

The makeup water for the cooling towers (6500 to 7500 gpm) and ash handling system has a pH of about 8.3 to 8.4. Based upon corrosion-precipitation control criteria, the plant operators add some 300 gal. of sulfuric acid to the cooling tower makeup water each day. The also chlorinate for algae control six times per day for 30 min. to get an 0.75 ppm residual. This residual disappears in about 2 hours.

Based upon a dissolved solids limitation, the plant operators continuously withdraw 500 gpm from the tower basins. This blow-down water is returned directly to the river.

A separate water supply is used for fly ash handling purposes. The 85 percent efficient "multiclone" separators remove about 800 tons per day of fly ash from the stack emission. (Fly ash content of the coal is about 15%). Due to the 5 percent lime content in the Clinchfield coal, pH of the ash slurry is quite high, about 12.0. The ash slurry is settled in a lagoon from which the over-flow drains to the ½ acre recirculation pond, shown in Fig. 10. Makeup water is pumped from the Clinch River to the recirculation

pond. Noticeable on the day of our visit were lime deposits around the shores of this pond. Fig. 11 shows tower 4, the Clinch River, the ½ acre fly ash recirculation pond, and the fly ash disposal area in the background.

The decision to use cooling towers at the Clinch River plant was precipitated by an inadequate supply of acceptable quality water for once-through cooling, as was the case for every plant we visited in our eastern tour. Selection of the four mechanical draft towers in 1958 to serve Units 1 and 2, was almost automatic since large natural draft towers were not in use in the United States at that time. In 1961, The addition of the fifth, larger mechanical tower to serve Unit 3, was based on (1) the satisfactory performance of the first four towers and (2) space limitations.

Each of the first four towers was designed for an operating range of 19°F and "approach" of 8°F at a cold water temperature of 70°F and a flow of 55,000 gpm. (The "approach" is the difference between cold water temperature leaving the tower and the ambient wet bulb temperature of 70°F and flow of 110,000 gpm.)

During the Marley acceptance tests, the data on towers 1 through 4 yielded an approach 0.2°F. lower (better) than expected whereas tower 5 yielded an approach 0.65°F lower than expected.

Operation of these towers has been mostly maintenance free, with occasional servicing of fans, couplings, etc., required. No serious problems were reported, however. There has been no

problem with the wood fill material which is redwood in towers 1 through 4 and treated Douglas fir in tower 5. Total power requirements for the fans of all five towers is 4400 HP.

Icing control requires that minimum tower water temperatures be maintained above 50 ^{o}F during the winter months. Fans are reversed on problem cells to accomplish this when necessary. Although reversing the fans causes a reduction in tower efficiency, the power plant condensers have been designed to accommodate some variability in tower operating range. Note also that higher winter temperatures are not as critical to condenser efficiencies as higher summer operating temperatures.

Because the mechanical draft towers at Clinch River can be "operated" to some extent, the plant personnel have a greater interest in performance data than personnel we talked to at plants with natural draft towers. Tower influent and effluent water temperatures, wet and dry bulb air temperatures, and condenser back pressures are recorded continuously at the Clinch River Power Plant. Full scale performance tests are also conducted annually.

The impact of the Clinch River Plant on water quality is minor with just the blowdown water being returned to the river. Ash handling water is recirculated.

According to the operating personnel, the cooling towers contribute nothing to naturally occurring fogging or icing conditions in the vicinity of the power plant. On rare occasions, at extremely cold temperatures, there has been light snowfall within 100 yards of the towers.

The worst weather conditions in terms of plume density and persistence are the cold, early morning hours of high relative humidity. Even then, however, the plumes rise and dissipate rapidly. Convection eddies from the hillside adjacent to tower 5 occasionally cause "short-circuiting" of vapor from tower 5 to tower 4. (Fig. 12 shows tower 5 and the hillside next to it.) This is not a serious problem. During summer months of warm, dry weather the tower plumes are barely visible.

The A.E.P. Service Corporation, New York, began a photographic study of the Clinch River and Big Sandy cooling tower plumes in November 1968. Photographs of the plumes are taken twice daily during this continuing study. The time, date, air temperature, and relative humidity are shown on each photograph. Samples of the study results showed dense plumes during periods when the relative humidity exceeded 75 percent. These plumes were intact and rising. No fogging problems were noted.

As at each of the other plants visited we were favorably impressed with the personnel at Clinch River. Consequently we respected their judgment of plant and cooling tower performance. The Clinch River staff were pleased with the overall performance of their mechanical draft cooling towers.

BIG SANDY PLANT; LOUISA, KY.

Location: Near Louisa, Kentucky, on the Big Sandy River

Owner: Kentucky Power Company (American Electric Power System)

Type: Coal-fired (mine-mouth)

Capacity: 265 MW from 1 unit
(800 MW additional in 1969)

Condenser Cooling Water Requirement: 120,000 gpm
(248,000 gpm for 800 MW unit)

Plant "Makeup Water" requirement and source: 5000 gpm from Big Sandy River (This will increase to 10,000 gpm in 1969)

Waste Heat Treatment: 1 Marley, hyperbolic (counter-current type) cooling tower (New unit will use 1 Marley hyperbolic, crossflow cooling tower.)

From the Tri-State Airport at Huntington, W. Va., we drove down to the Big Sandy Plant near Louisa, Ky., on the morning of Dec. 19, 1968. It was overcast and mild with a light breeze when we arrived at Big Sandy (T_a=56 ^{o}F, RH=60%, W=12 mph). The cooling tower plume from their single 265,000 MW unit was thin, hardly discernible, as we approached the plant. Fig. 13 shows the Big Sandy Plant and its water source, the Big Sandy River. The operating tower is on the right in the photograph. The new 800,000 MW unit was not yet in service.

Messrs. R. Marshall and Greer Matthews of the Big Sandy Plant, and Mr. Tom Miskimen, AEP, New York, met us at the plant.

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Because of our tight schedule, we conducted our discussion with these gentlemen over lunch and visited the plant briefly before returning to the Tri-State Airport.

Makeup water for the Big Sandy power plant is pumped from the Big Sandy River adjacent to the plant. With the new unit in operation pumping requirements are expected to be about 10,000 gpm including evaporation, blowdown, and ash handling water. Pre-treatment of the makeup water includes acid for pH control and chlorination for slime control.

A new fly ash sedimentation pond has been located several hundred feet from the power plant. Ash handling water will consist of treated wastewater (power plant), "Bottom as' ' pond supernatant, and blowdown water. Overflow from the fly ash pond will go to a dry creek and thence to the Big Sandy River.

A cooling tower was needed at Big Sandy because not enough water is available for once-through cooling. Here, again, the tower has been incorporated as an economic factor in plant location. At the time of dedication, January, 1963, this was the first natural draft, hyperbolic cooling tower in the United States. An historic marker is shown in Fig. 14, to document this event.

The original tower at Big Sandy incorporates an exterior annular trough for distribution of warm water to the packing. This trough can be seen just above the supporting columns on the tower in Fig. 15. For control of icing, the flow t- one-half of the distribution trough is cut off. Warm water then overflows the other

one-half, cascades down the tower sides and melts external ice formation.

As at the other plants visited, operations at Big Sandy have had little effect on water quality. Use of the blowdown water for ash handling will further diminish water quality effects.

Similarly, there appeared to be no significant air quality effects. In fact, the plant personnel commented that they have not received even "crackpot complaints" despite the uniqueness of their cooling facilities.

Severe fogging conditions are endemic to this area. No additional problems have been attributed to the cooling tower. Ordinarily the plume readily dissipates. During worst weather conditions, however, the plume may travel one or two miles.

There is an occasional light misting from the cooling tower with no problems resulting. No icing problems have occurred in the vicinity of the tower. It was noted that the main transformer banks are located within 100 ft. of the original cooling tower.

As mentioned in the discussion of the Clinch River power plant, AEP Service Corporation is preparing a report on atmospheric effects from daily photographs of the Big Sandy cooling tower plume. To date these photographs have documented satisfactory plume dissipation characteristics.

The original Big Sandy power plant incorporates a multiclone unit for fly ash emission control. Separation of fly ash is about 85 per cent effective with this unit. Although some fallout has

been reported from the stack emission and mixing of stack emission and tower plume, there have been no complaints of acid (SO_2) misting. SO_2 problems are minor anyway with less than 1 per cent sulfur content in the coal.

A 98 per cent effective electrostatic precipitator is being installed in unit 2 along with an 826 ft. chimney. This combination will serve both generators. The multiclones and old chimney will then be taken out of service.

ALAMITOS STEAM STATION, LONG BEACH, CALIF.

Location: Between Los Cerritos Channel and San Gabriel River, 2 miles from Pacific Ocean, in Long Beach, California

Owner: Southern California Edison Company (SCE)

Type: Gas/oil fired

Capacity: 1950 MW from 6 units

Condenser Cooling Water Requirement and Source: 882,000 gpm from Los Cerritos Channel

Waste Heat Treatment: None; once-through cooling with discharge into San Gabriel River.

Messrs. Hildebrandt and Patterson returned to Portland on December 19, following the Big Sandy visit. The four remaining tour participants were joined by Mr. J. L. Agee, Northwest Regional Director, FWPCA, and Mr. Glen Carter, OSSA, in Los Angeles on the morning of Dec. 20 for the Alamitos and San Onofre tours. We were also accompanied by Mr. John Merrell, R & D Officer, SW Region, FWPCA, who acted as our contact with Southern California Edison (SCE).

Messrs. Milton LaPoint and Charles Richardson of SCE picked us up at the Los Angeles Airport for the drive down to Long Beach and the Alamitos Steam Station. The Long Beach weather on Dec. 20 was cool, clear, and breezy. This was an exceptionally fine day with no trace of smog.

We were met at the Alamitos Station by Mr. Leo Udy, Plant

Manager, and Messrs. Jerry Stipanov and E. L. Kerry, SCE, Los Angeles, who were our hosts for the morning. Representatives of the Los Angeles Regional Water Quality Control Board and Los Angeles County were also present during our discussions of the power plant.

The six-unit, 1950 MW, Alamitos Plant is located between the Los Cerritos Channel and San Gabriel River about 2 miles from the Bay. Fig. 16 is a map showing the location of the Alamitos Plant and the 1540 MW Haynes Plant (Los Angeles Dept. of Water and Power). Fig. 17 shows the Alamitos Plant and its discharge channel, the San Gabriel River. These are heavily rip-rapped, channelized watercourses that look very much like large irrigation canals. Without the Alamitos Station and Haynes Plant, there would be little or no flow in either channel during the dry irrigation season. Tidal effects for Los Cerritos and San Gabriel extend upstream about 4.5 miles at high tide.

Eighteen years ago the San Gabriel River (drainage area = 240 sq. mi., annual yield = 25,000 AF) was a meandering stream of poor quality. Black benthos deposits and low pH and dissolved oxygen values were characteristic. The natural seasonal range of temperatures for Los Cerritos and San Gabriel is 55° F in January to 74° F in August.

Mr. Nerevs Richardson, Los Angeles Regional Water Quality Control Board, explained that the water quality standards which apply to the Alamitos Steam Station require: pH from 7.0 to 8.5;

D.O. ≥ 8.5; color and odor aesthetically satisfactory; and no adverse ecological changes due to temperature changes. There are numerous upstream municipal and industrial waste discharges to the San Gabriel River in addition to the Alamitos and Haynes power plants. Mr. Merrell had commented earlier that cattle feed operations discharge nutrients to the San Gabriel upstream of the power plants.

Cooling water for the Alamitos Steam Station is pumped from the Los Cerritos Channel through two intakes, one intake for Units 1 to 4 and the other for Units 5 and 6. Maximum pumping rate is 880,000 gpm. Fig. 18 shows the intake canal to the Alamitos Plant. The litter shown in the foreground of Fig. 18 has been carried up to the Alamitos Plant from the marina shown on Fig. 16.

Alamitos Steam Station uses the ocean water on a once-through basis for condensing steam to water. There is no fresh water available at this location to satisfy the consumptive use requirements for any wet-type cooling tower or a cooling pond. Consequently, these were not practicable alternatives to once-through cooling.

Intake temperatures average 65 to 70° F during the summer months. Temperature increase across the condensers is reportedly about 15° F, although effluent temperatures are not monitored. The intake water is not pretreated for slime control or pH adjustment. Hence, the only change in water quality through the power

plant is the increase in temperature. Since pumping rates are held constant, the temperature increase will vary with plant load. Also, average heat rates (energy required to produce a kilowatt-hour of electricity) under fluctuating power demand are higher than design.

Operating water temperatures at Alamitos are apparently satisfactory at this time. Higher intake water temperatures would require increased pumping capacities, decreased efficiencies, or both.

The impact of Alamitos Steam Station on air quality should be small. Rigid controls on stack emissions dictate that the power plant operates on natural gas during critical weather conditions and oil otherwise. The oil is low in sulfur (0.3 per cent) and ash (0.004 per cent) content and is imported from Indonesia for this purpose. Special bags, coated with dolomite, filter out the remaining ash and SO_2 from the stack of one unit on a "demonstration" basis.

The impact of Alamitos on water quality could be considered beneficial, since it provides a substantial flow of ocean water (heated 15° F) to the San Gabriel River. Similarly, a circulation current through the marina areas of Los Cerritos Channel is provided by the cooling water intake pumps.

There have been no environmental studies in the San Gabriel River relative to operations of the Alamitos Plant. Los Angeles County has collected some temperatures, however. One set of

summer data indicated an ambient (ocean) temperature of 62° compared with 82° in the San Gabriel River downstream of the Alamitos and Haynes power plants.

Because of the prevailing drift of currents along the coast, there has been no problem of recirculation between San Gabriel River and Los Cerritos Channel. The intake water temperature records at Alamitos tend to verify this conclusion. The commentary on Alamitos as we completed our discussion was to the effect that location of thermal power plants to utilize "dead end channels" like Los Cerritos and San Gabriel for intake and discharge of cooling water may be the key to siting problems of these plants in terms of thermal effects. It was pointed out by Mr. Carter, OSSA, however, that there is a major difference between the Alamitos location and Oregon coastal sites. The seasonal water temperature range in the Long Beach area is some 20° F compared with less than 5° F along the Oregon coastline. Furthermore, the highest water temperatures along the Oregon Coast are 5° F lower than the lowest temperatures at Long Beach. Consequently, the impact of small temperature changes upon the cold water, stenothermal fishery in Oregon would be more severe than for the warm water, eurythermal fishery at Long Beach.

In any case, the sport fishery in the Alamitos area has not suffered because of the power plant cooling water discharges. In fact, the sport fishing boats reportedly congregate in the area of these discharges. According to Mr. Merrell, the warm water

plumes "enhance" local water skiing and certain fish runs.

SAN ONOFRE NUCLEAR GENERATING STATION; SAN CLEMENTE, CALIF.

Location: On an 83 acre tract 4 miles southeast of San Clemente, Calif., within the Camp Pendleton Marine Base.

Owner: Southern California Edison Co. and San Diego Gas and Electric Co.

Type: Nuclear

Capacity: 450 MW from 1 unit

Condenser Cooling Water Requirement and Source: 350,000 gpm from Pacific Ocean.

Waste Heat Treatment: None; once-through cooling with ocean outfall ½ mile offshore.

From the Alamitos Station in Long Beach the SCE representatives drove us down to the San Onofre Nuclear Generating Station near San Clemente. Fig. 19 shows the San Onofre Nuclear Generating Station as seen from the visitor center overlooking the plant. San Onofre is situated on a less than 10-acre portion of the 90-acre tract of land leased from Camp Pendleton at an annual cost of $100,000. The plant was dedicated in January 1968, but was "shut down" for wiring adjustments from April to September 1968. There was, and is, no problem with the reactor or support equipment.

We were met at San Onofre by Mr. Joe Reeves, Chemical Engineer, SCE, in Los Angeles, who acted as our host. Mr. Reeves conducted us on a tour of the station and answered questions.

For perspective, it should be noted that, although San Onofre

is rated at 450 MW, in terms of waste heat to cooling water, it is equivalent to about a 720 MW fossil-fueled power plant. This is because of the lower operating pressure and temperature inherent in nuclear power generation using pressurized water as the primary reactor coolant.

The secondary coolant, ocean water, is pumped through an intake 3200 ft., offshore and 15 ft. below the water surface. A concrete "velocity" cap placed over the top of the intake effectively minimizes the number of fish drawn in with the cooling water. The heated cooling water is returned through a single 12 ft. diameter outfall 2600 ft. offshore and 15 ft. below the water surface. Both the intake and outfall are located in 30 to 35 ft. of water.

The cooling water is chlorinated for algal control at the pumpwell. Chlorination is continuous in sufficient quantities for a 1 to 3 ppm residual.

Every 5 or 6 weeks the cooling water flow is restricted causing temperatures to rise in the conduits to 105^{o} F. These high temperatures are maintained for 2 hours to control growth of black mussels and barnacles. This minimizes clogging and damage to the condenser lines. As a part of this procedure, circulation through the outfall and intake conduits can be reversed at the discretion of the plant operator.

Because this is a nuclear generating station which incorporates once-through cooling with ocean water, there is no potential

for air quality problems equivalent to stack emissions or cooling tower plumes.

The effect of the San Onofre station on offshore water quality has been the subject of pre- and post- construction ecological studies as required by WQCB. A program was arranged with the State Resources Agency in May 1964 for 2 years of pre-construction and 1 year of post-construction studies. However, with construction delays and the 1968 shutdown, there have now been some 3 years of pre-construction and 6 months of post-construction studies up to this time. Much of the field work has been done by Marine Advisers, Inc., La Jolla, Calif.

Data collected include current measurements, turbidity, coliform counts, salinity, dissolved oxygen, and benthic flora and fauna. Also monitored has been the movement of sand from the offshore construction pad used as a platform for installation of the intake and outfall conduits.

Field studies were initiated in 1964 with the establishment of transects for sampling; two north of the station, one along the intake-outfall lines, and one south of the plant. Quarterly surveys are made along these transects for benthos examinations. Quarterly, or semi-annual, surveys are also made at 12 biological sampling stations for plankton identification.

A grid system of 32 buoys was set up for bi-monthly temperature measurements, turbidity (Secchi Disk) determinations, and visual checks for plankton blooms. Dispersion studies have

been conducted using up to 12 surface drogues in the vicinity of the intake and outfall.

Finally, representative samples of fish and bottom dwellers are collected for determination of isotope uptakes.

Areal influence of the San Onofre cooling water has not been accurately determined. Mr. Reeves estimated that temperature differences decrease to less than 1° F within ½ mile of the outfall. This compares to a temperature difference of 6 to 7° F at the water surface directly above the outfall. Temperature rise across the condensers at San Onofre is 19 to 20° F. Of this temperature increase, 6 to 7° F are dissipated by conduction in the outfall conduit and another 7° F by dilution between the outfall and water surface.

One set of data which Mr. Reeves showed us was for February 22, 1968. These data indicated an ambient ocean temperature of 57 to 58° F. At the water surface, above the outfall, the temperature was 65° F. This means that some 11 to 12° F was dissipated by conduction and dilution between the condensers and the water surface. From the outfall, the warm water reportedly spreads as a relatively thin layer.

Ambient ocean temperatures in August reach a maximum of 76° F at the water surface and decreases to about 65° F at a depth of 35 ft.

To date, Mr. Reeves commented that the only noticeable ecological change at San Onofre has been the increase in fishing boat

activity in the area of the outfall.

III. CONCLUSIONS

The conclusions are divided primarily on the basis of the power plants visited during the tour and potential sites here in the Northwest. Secondary subdivisions relate to the different locations, types of fuel, and types of cooling methods used.

POWER PLANTS VISITED DURING THE TOUR:

A. Coal-fired power plants in eastern United States

1. General Comments:

a. The five coal-fired thermal power plants visited in the Alleghany Plateau and the Appalachian Mountains were all built in remote locations close to their sources of coal (mine-mouth). These power companies have found it cheaper to transmit high-voltage power to the distant "load centers" than to ship coal long distances to the power plants. Use of cooling towers and ponds have made these mine-mouth locations practicable in view of inadequate water supplies for once-through cooling.

b. All five locations are in wooded, hilly areas not utilized extensively for farming except for the Christmas tree farms near the Keystone Station.

c. Of these five power plants, only the 1.8 million KW Keystone Station rejects as much heat to the condenser cooling water as a 1.0 million-KW nuclear power plant. This is because waste heat quantities to the condenser cooling water from modern fossil-fueled power plants are 40 to 60 percent lower than for nuclear power plants.

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2. Impact on water quality of blowdown (water drawn from cold water basins of cooling towers to prevent build-up of solids concentrations) and ash-handling water:

a. Blowdown water contains chemicals used for pH adjustment and slime control. At 3 out of 4 plants involved, this blowdown water is used for ash-handling purposes eliminating direct return to the water source.

b. Ash handling water at all 5 plants is lagooned and/or chemically treated before return to the river. (At Clinch River this water is recirculated.) No adverse effects from the discharge of ash handling water were evident or reported. Because of the generally poor quality of the receiving waters, however, minor adverse (or beneficial) effects would not be evident.

3. Impact on air quality of the cooling operations:

a. Mechanical draft cooling towers (Clinch River Plant)

(1) The four 10-cell cooling towers and the one 14-cell cooling tower at the Clinch River Plant function satisfactorily to cool the condenser water for three 225,000-KW units. Problems of operation and maintenance are minimal with the most troublesome problem being the couplings between electric motors and fans.

(2) Short-circuiting of the plumes occur only when unusually strong convection currents carry water vapor from tower 5 near the valley wall to the intake of tower 4.

(3) Although located in a constricted river valley where ground fogs are common, power plant personnel reported that

cooling tower discharges do not increase local fog occurrence or density. Visible plumes vary in size, depending on prevailing atmospheric conditions, but dissipate while rising.

(4) Precipitation (e.g. drizzle) and icing in surrounding areas during cold weather, does not occur according to power plant personnel. On very rare occasions at ambient air temperature of -20°F and lower, fallout of fine snow or ice crystals has occurred in the immediate vicinity of the towers and within the confines of the power plant property.

(5) Power costs to operate the cooling towers was considered to be small. (Total power required to run the fans is 4400 HP. This is about 0.5 percent of the plant output.)

b. Natural draft cooling towers (Keystone Generating Station, Ft. Martin Power Station, Big Sandy Plant).

(1) The cooling towers at all 3 plants were reported to perform (from a water cooling standpoint) as well or better than manufacturer specifications. There was some indication at two plants that the towers had been "oversized" to assure satisfactory performance.

(2) Large capacity cooling towers evaporate large volumes of water into the atmosphere (up to 35 cfs). The cooling tower plumes vary widely in size, density and behavior depending on weather conditions. They may be characterized as:

(a) Small, wisp-like, barely visible on warm, dry days.

(b) Large and dense on cold, humid days; dissipate more slowly. These plumes are visible from vantage points several miles away.

Aside from localized turbulence at one plant, all of the cooling tower plumes were observed to have good rising characteristics. These plumes are reported to have good rising characteristics under essentially all weather conditions. The natural draft cooling tower plumes reportedly:

(a) Do not contribute to local ground fogging or icing conditions. No "area" problems were observed to result from cooling tower operation. In every case, this was reported not to be a problem despite heavy, natural fogging conditions.

(b) Do not add significantly to low overcast conditions; thickening of the overcast is of local extent. No problems or complaints were reported.

(3) Direct carry-over of entrained water droplets from the towers is effectively controlled by "drift eliminators" (angular vanes) in the towers. Misting from carry-over was not reported to be a problem.

(4) There were no complaints of "acid misting" due to cooling tower operations, although the tower plumes were reported to mix occasionally with stack emissions.

(5) The cooling towers visited were not aesthetically displeasing to the tour participants. Public acceptance of the towers, at least in these remote locations, appeared to be satisfactory.

c. Cooling pond (Mt. Storm Power Station)

The Mt. Storm cooling pond was reported to perform very satisfactorily.

(1) Cooling ponds evaporate less water than cooling towers for equivalent sized plants.

(2) Localized "steam fog" and immediate shoreline icing conditions were observed under the cold weather conditions during our visit. Steam fogs such as this should not occur during the warm recreational season.

(3) Cooling ponds may contribute to natural ground fogs prevailing over the area in which they are located. Under no conditions of weather, however, were fogging or icing reported to be a problem to the adjacent highway or power plant at Clinch River.

B. Coastal locations; once-through cooling with sea water

1. General comments: Two types of caostal sites were observed.

a. With intake and discharge, "dead end" channels located on opposite sides of the power plant. Cooling water is withdrawn from one channel, heated, and discharged to the other. Natural fresh-water flows in both channels are small relative to the cooling water flow. Discharged cooling water is diluted with tidal water thereby reducing temperature differences at the mouth of the discharge channel.

b. With intake and discharge conduits extending into the sea from an open coastline.

The San Onofre Nuclear Generating Station in particular, is a good example of an aesthetically unobtrusive installation with its compact, neat lines, pleasant colors, and careful landscaping.

2. Impact on water quality:

a. There were no evident or reported water quality problems associated with either coastal site visited. Sport fishing, in fact, appears to be more popular in the immediate areas than before plant construction. (Note, however, that these are sub-tropical salt water fishes, tolerant to rather wide ranges in water temperature.) Areal extent of the warm water at both locations was limited and was estimated to be confined within ½ mile of the San Onofre outfall.

b. The induced circulations in the Alamitos intake and discharge channels were reported to be beneficial to these otherwise "dead" tidal prisms.

3. Impact on air quality: Thermal power plants using sea-water for once-through cooling eliminate all impacts on air quality which may result from cooling tower emissions.

POTENTIAL POWER PLANT SITES IN THE NORTHWEST:

A number of conclusions can be reached from our observations and discussions during the tour relative to the environmental aspects of power plant siting in the Northwest. Some questions, however, must remain unanswered until more is learned of individual locations.

A. Cooling towers

Based upon our personal experience, we could see no reason to distinguish between mechanical draft and natural cooling towers relative to generalized conclusions on environmental impacts, except that the plumes from natural draft cooling towers will be emitted at much higher elevations than the plumes from mechanical draft cooling towers will be emitted at much higher elevations than the plumes from mechanical draft cooling towers.

1. Impact on water quality

a. For nuclear generating stations, ash handling water is non-existent, therefore not a problem. For fossil-fueled plants, like the Centralia, Washington, station under construction, the ash-handling water will be amenable to treatment and can be recirculated (or returned after treatment to the receiving stream).

b. There should be no need for cooling water pH adjustment in the Northwest. The blowdown water will have to be treated before it is returned to the receiving stream, however, to neutralize slimicides and/or algacides and to reduce dissolved solids concentration.

2. Impact on air quality:

a. Local misting and icing due to carry-over of water drops from the towers should not be a problem with efficient "drift eliminator" design.

b. Direct precipitation from the tower plumes in the form of rain or drizzle should not occur in the absence of condensation nuclei provided by some external source. Even where these nuclei are provided by industrial stack emissions or other sources, there are not sufficient data for a definitive conclusion. (Note, however, that acid misting from this combination of cooling tower plumes and stack emissions was not reported to be a problem at any plant visited during the tour.)

c. Cooling towers should not cause or contribute to ground fog at potential Northwest sites. Available data indicate that natural fogging conditions are no worse here in the Northwest than at the locations visited in the Alleghany Plateau and Appalachian Mountains.

d. Cooling tower plumes would contribute locally to low overcast conditions.

e. The cooling tower plumes would always rise and dissipate. The distance required for dissipation under the worst conditions is reported to be on the order of miles. They would seldom, if ever, touch the ground except, perhaps, when influenced by strong winds. Note that all four tower locations visited in eastern United States were in valleys surrounded by hills several

hundred feet high.

B. Cooling ponds

1. Impact on water quality would depend upon conditions surrounding individual sites. Efficiently designed ponds, however, would perform satisfactorily. They would not evaporate as much water as cooling towers for equivalent size plants.

2. Impact on air quality:

a. "Steam fog" over the pond surface would occur during cold weather conditions, but should not present a problem to adjacent land areas. Steam fog should not occur during warmer weather (recreational seasons).

b. Cooling ponds would contribute locally to natural ground fog, but would not induce widespread ground fog during otherwise clear conditions.

c. Cooling ponds will not contribute to low overcast clouds.

C. Coastal sites with once-through cooling (sea water)

In terms of environmental effects, our observations tend to confirm the contention that coastal sites are preferable to inland sites for large thermal power plants.

1. Sites using tidal channels for intake and discharge:

a. Impact on water quality: There are insufficient data available on potential power plant sites in the Northwest to define water quality impacts of intake and discharge tidal channels. The Alamitos location at Long Beach is very favorable in terms of

geographical characteristics, offshore ocean currents, water temperature range, and type of sport fishery. Similar geographical characteristics with favorable currents may be obtainable in the Northwest, but water temperatures and the type of sport fishery will be less favorable for once-through cooling discharges.

We saw no evidence, however, that would indicate adverse effects, given a suitable geographical location. Temperature effects would be limited in extent by dilution within the tidal channel.

Losses of small fish through the condensers would occur but can be minimized by appropriate design of the intake conduit and screens.

In any case, extensive, pre-construction, ecological studies will be required to assure favorable conditions for once-through cooling with sea water at individual sites.

b. Impact on air quality: The discharge channel would exhibit air quality effects similar to those for cooling ponds.

2. Sites with ocean outfalls on the open coast:

a. Impact on water quality: Again, data from pre-construction ecological studies at individual sites will be needed to define water quality effects. Water temperatures and the type of fishery are significantly different from those at San Onofre. Adverse effects from ocean outfalls are unlikely, however, because of the limited extend of warm water.

Fish losses through the condensers can be minimized by appropriate design features.

b. Impact on air quality: None.

APPENDIX A

ILLUSTRATIONS

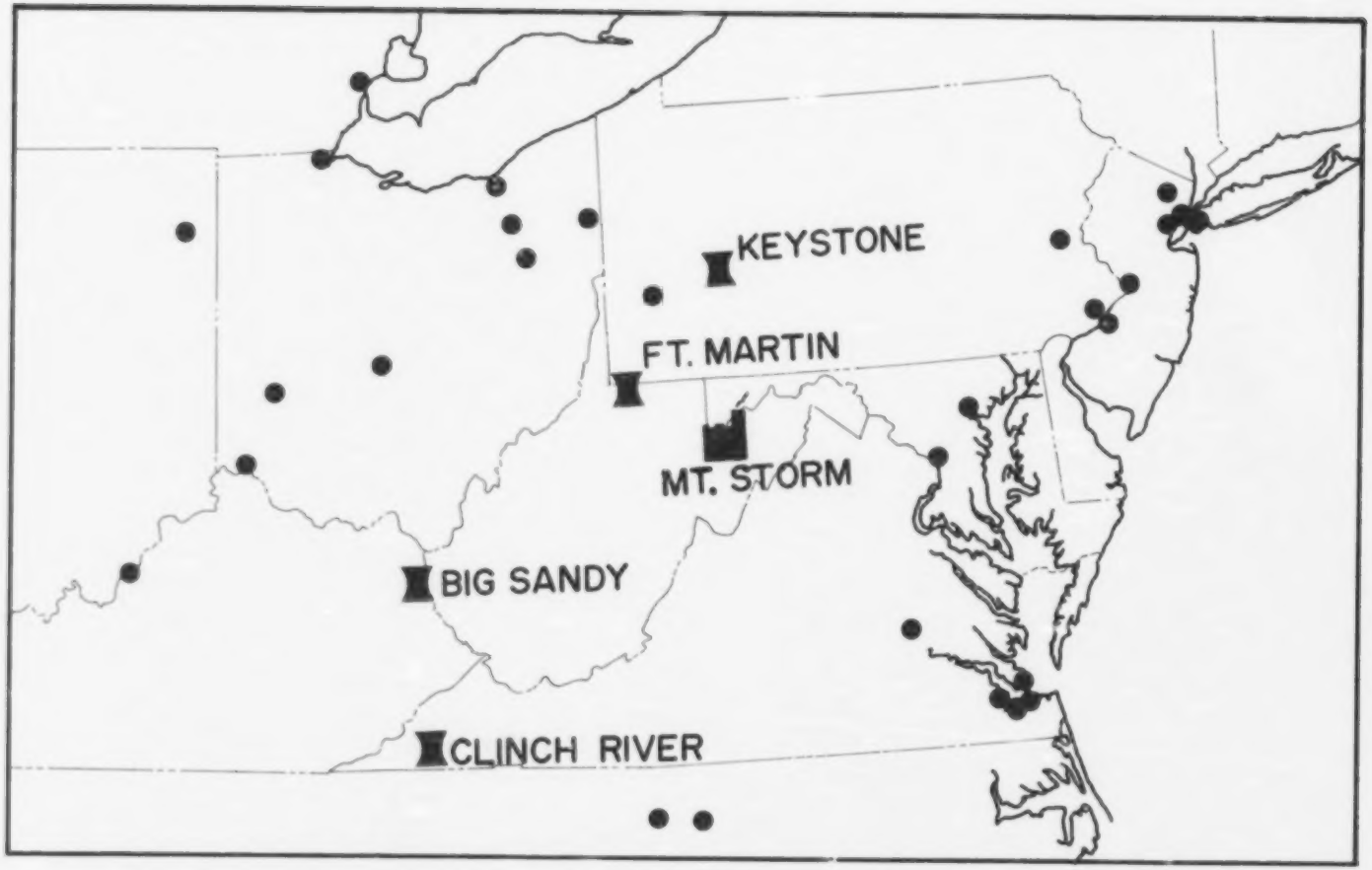

FIGURE 1. Coal-fueled powerplants visited in the eastern United States are all at mine-mouth locations in the Allegheny Plateau and the Appalachian Mountains. Dots identify cities with population of more than 100,000.

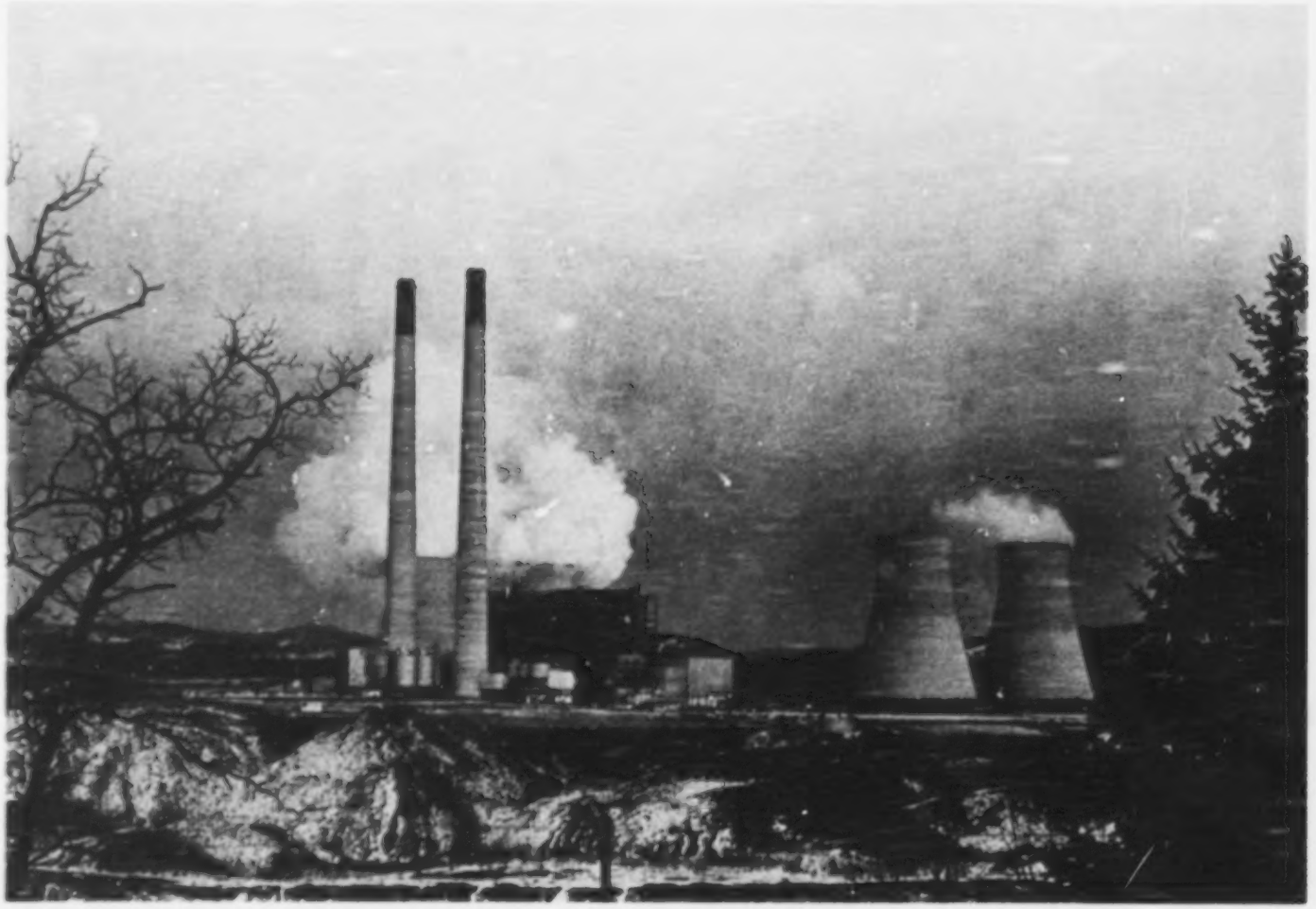

FIGURE 2. Keystone Powerplant located about 50 miles northeast of Pittsburgh, Pennsylvania. Heavy overcast after sunset. Wind speed, 20 mph. Temperature, 17°F.

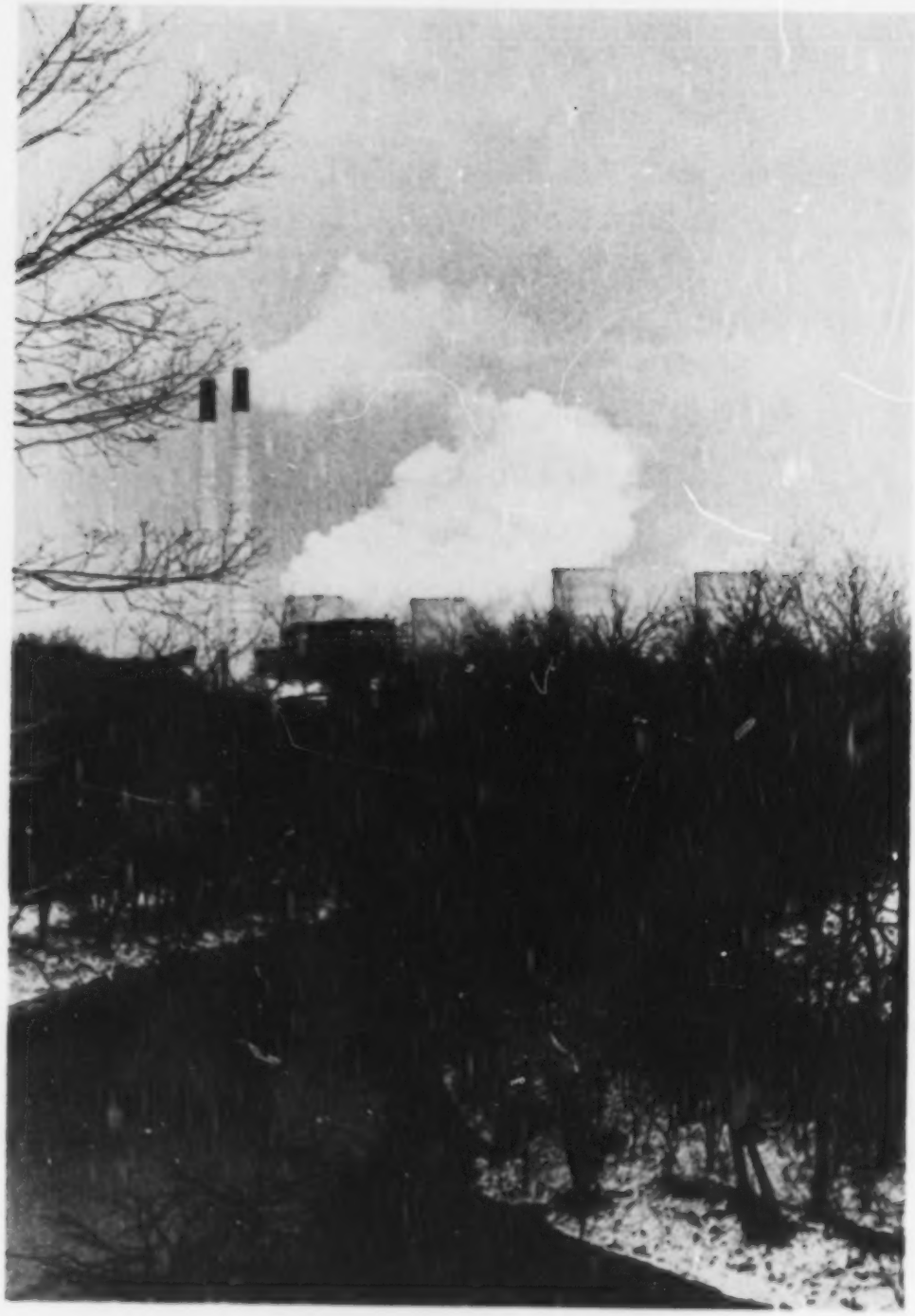

FIGURE 3. The huge Keystone Powerplant draws water from Crooked Creek flows which are maintained by releases from reservoir built on an upstream tributary.

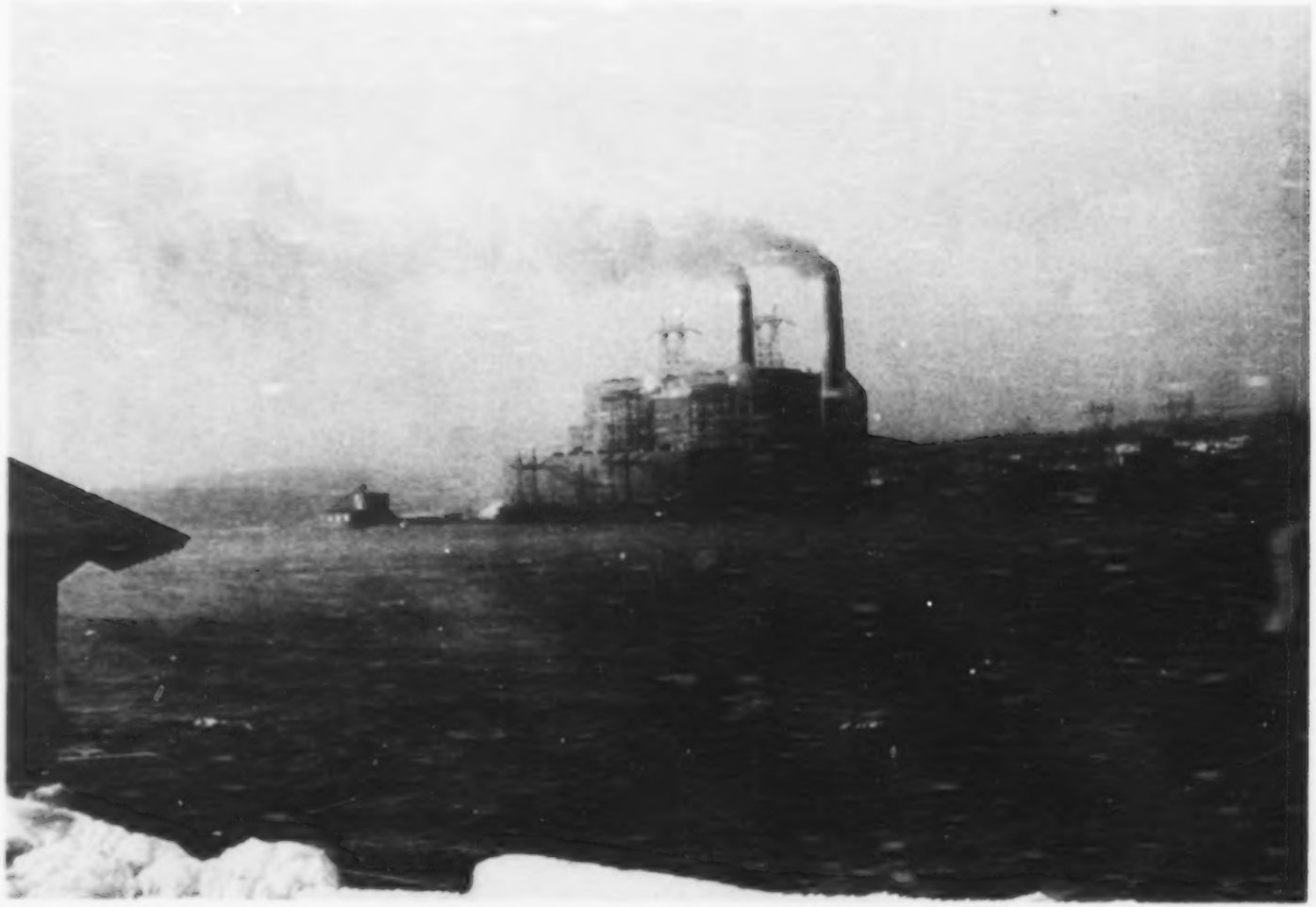

FIGURE 4. Mt. Storm Powerplant (W. Va.) and cooling pond formed by dam on Stony Creek. Steam fog rises in 20°F. temperature and 25-mph wind during mid-morning on a clear day.

FIGURE 5. One of two hot water discharges at lake level swirls to mix effectively in Mt. Storm cooling pond. Crest of dam which forms the 1200-acre lake is visible at upper left.

FIGURE 6. Visible plume rises high to fully dissipate in the 35°F. air at Ft. Martin Powerplant located on Monongahela River near Morgantown, West Virginia.

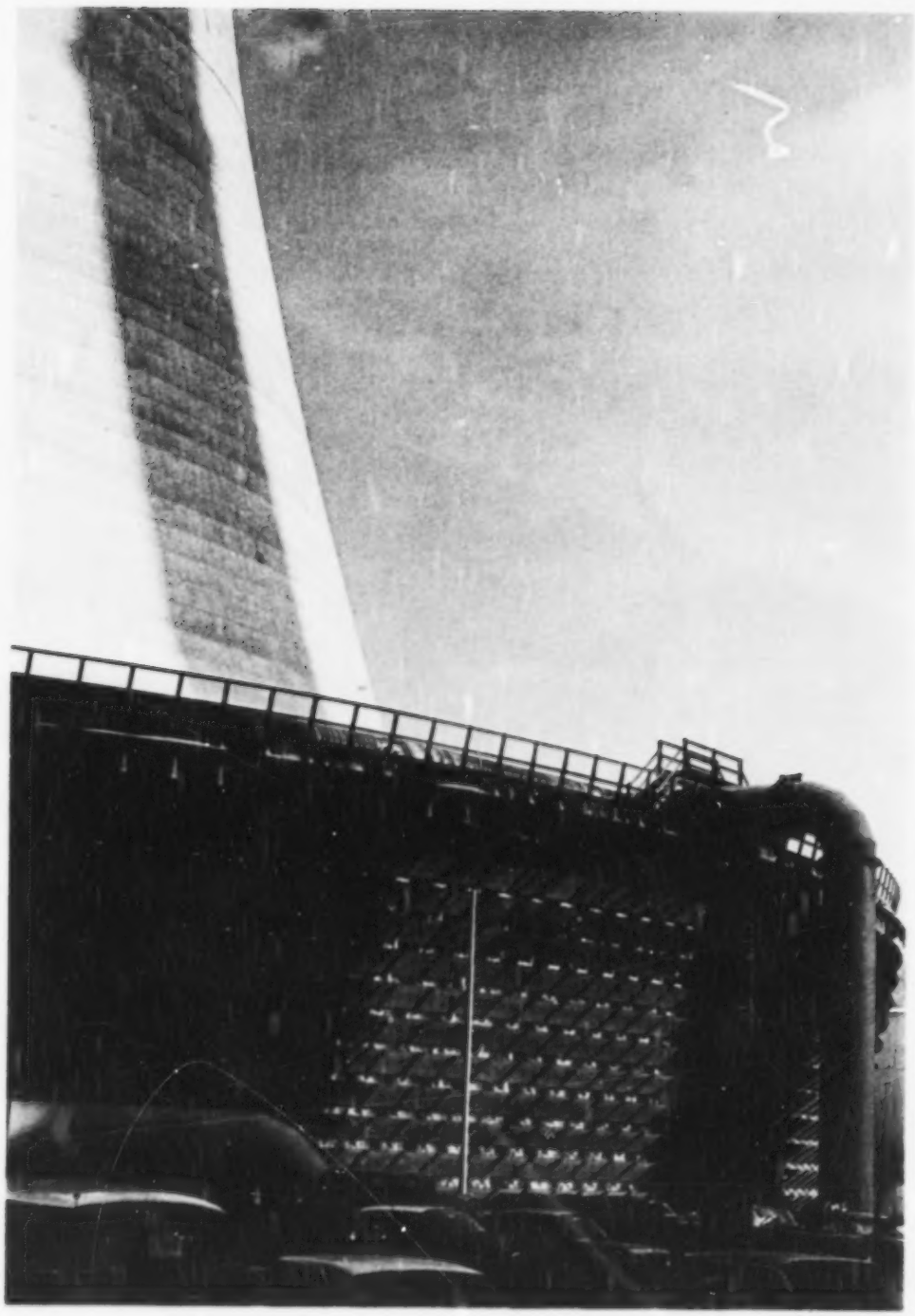

FIGURE 7. The cooling tower fill surrounds the base of cross-flow, natural-draft cooling tower at Ft. Martin Powerplant.

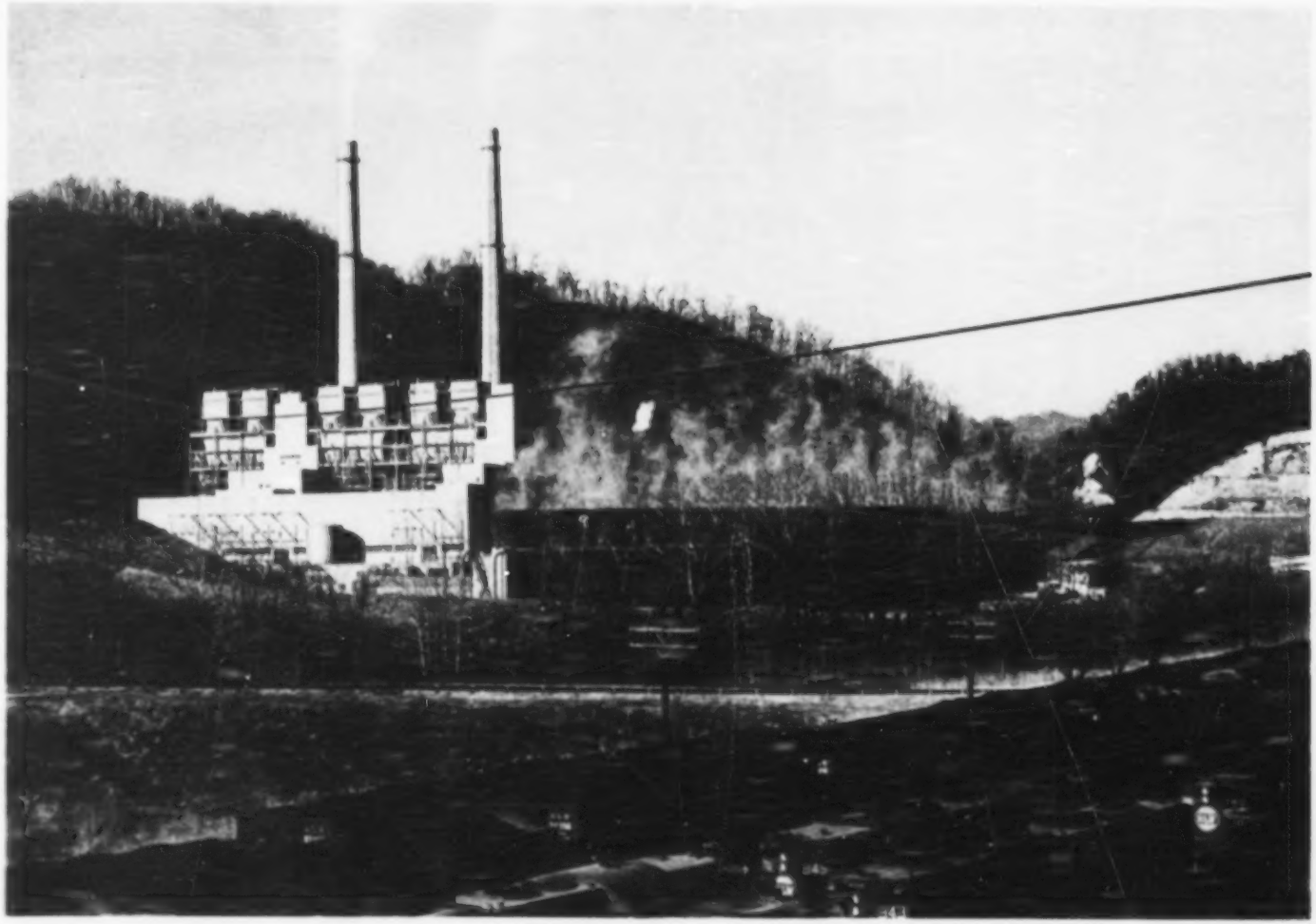

FIGURE 8. Clinch River Powerplant (Va.) uses mechanical draft cooling towers of the cross-flow, induced-draft type (fans in top blow air upward to pull air through packing on sides).

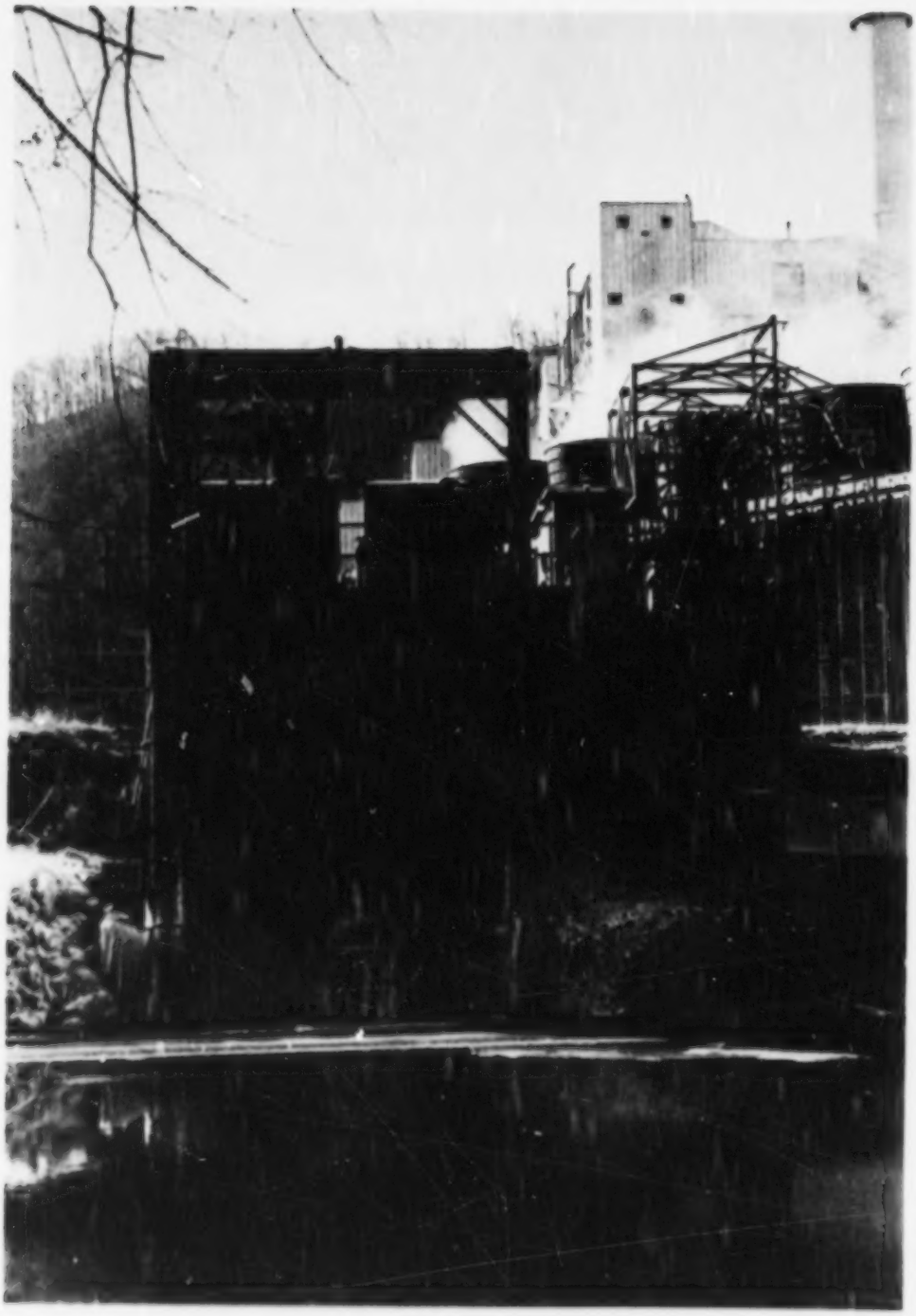

FIGURE 9. Water intake structure on the narrow Clinch River which flows around the Clinch River Powerplant in a large horshoe bend.

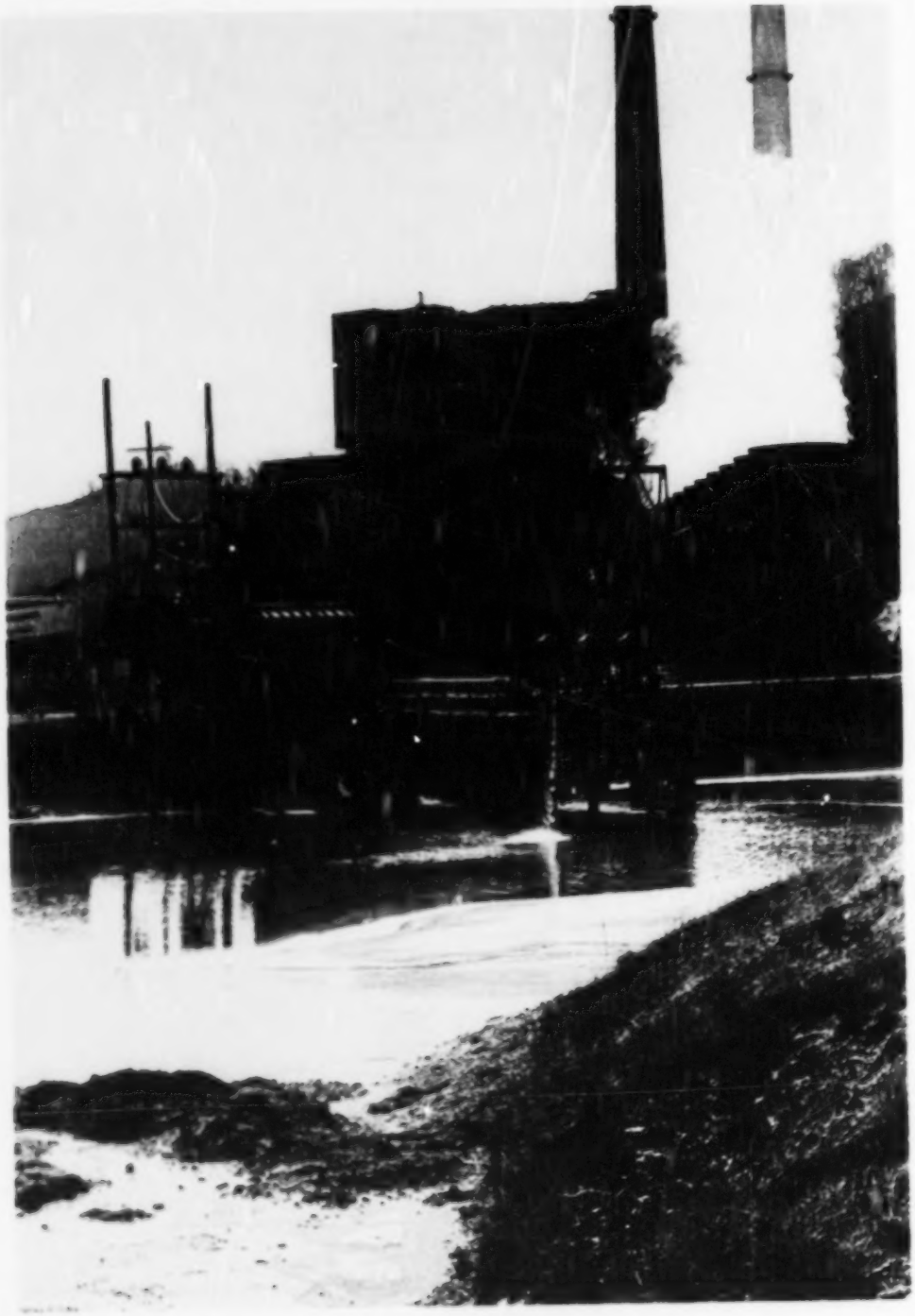

FIGURE 10. Recirculating ash handling water is pumped from this pond for reuse in the Clinch River Powerplant.

FIGURE 11. One of four cross-flow, induced-draft cooling towers serving two generating units at Clinch River Powerplant. Temperature 45°F. on a clear day with slight breeze.

FIGURE 12. A somewhat larger plume is emitted from the bank of 15 cells in the single cooling tower which dissipates waste heat from one of the three Clinch River units.

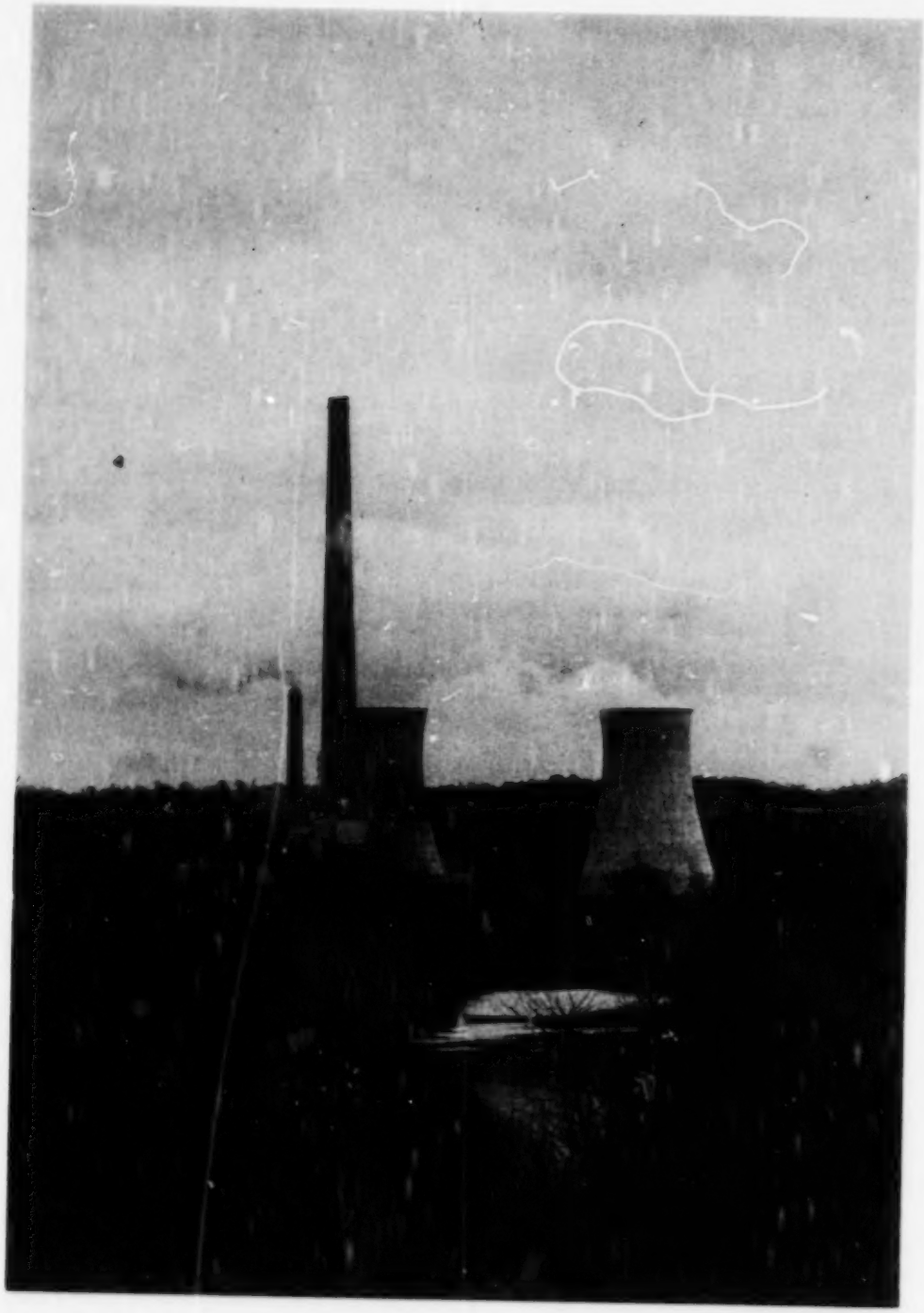

FIGURE 13. Limited water supply from Big Sandy River requires cooling towers for Big Sandy Powerplant. New tower on left is under construction. Temp. 61°F with light wind.

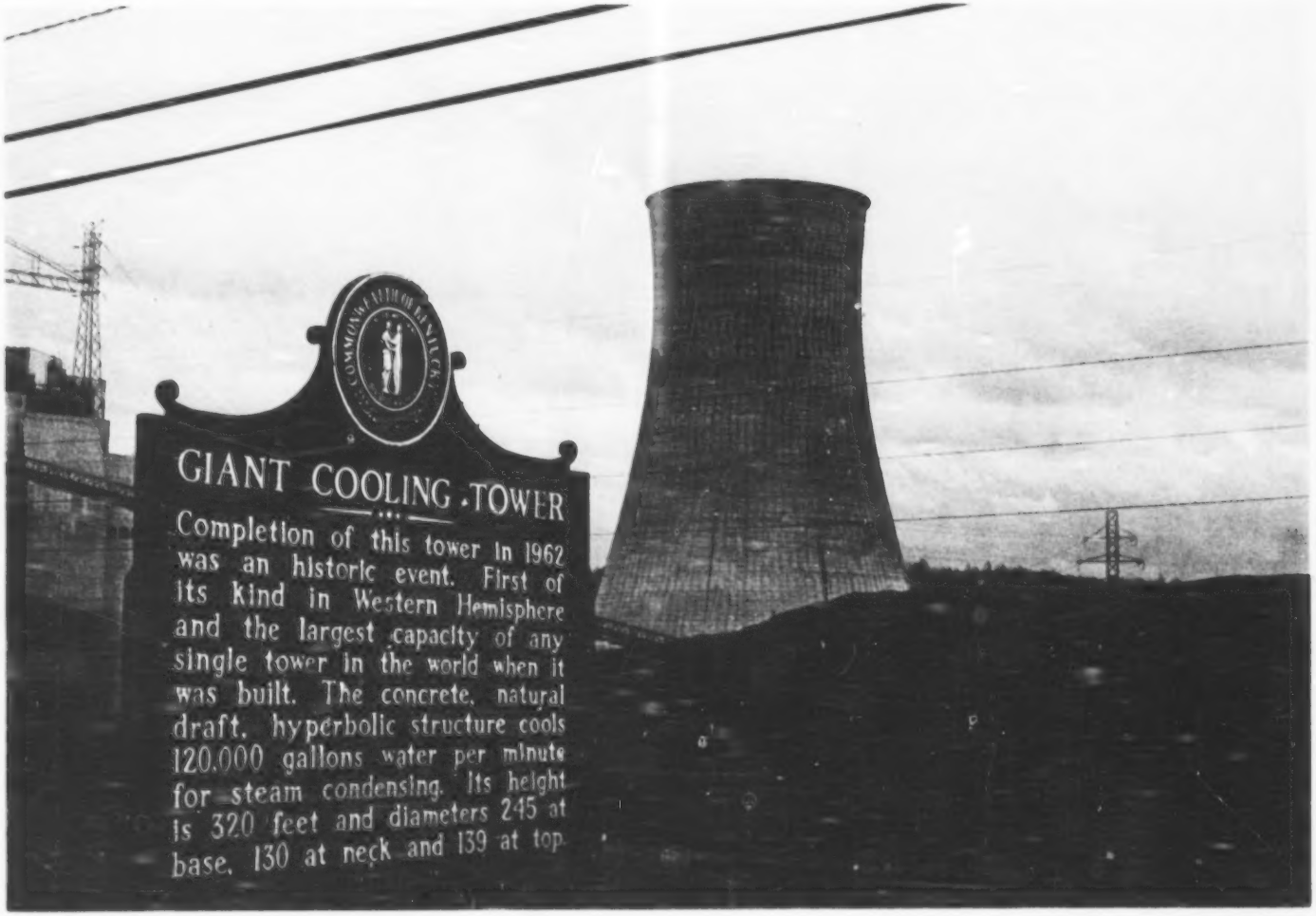
GIANT COOLING TOWER
Completion of this tower in 1962 was an historic event. First of its kind in Western Hemisphere and the largest capacity of any single tower in the world when it was built. The concrete, natural draft, hyperbolic structure cools 120,000 gallons water per minute for steam condensing. Its height is 320 feet and diameters 245 at base, 130 at neck and 139 at top.

FIGURE 14. Historical marker on U. S. Highway 23 adjacent to the Big Sandy Powerplant identifies the first natural-draft cooling tower built in the United States.

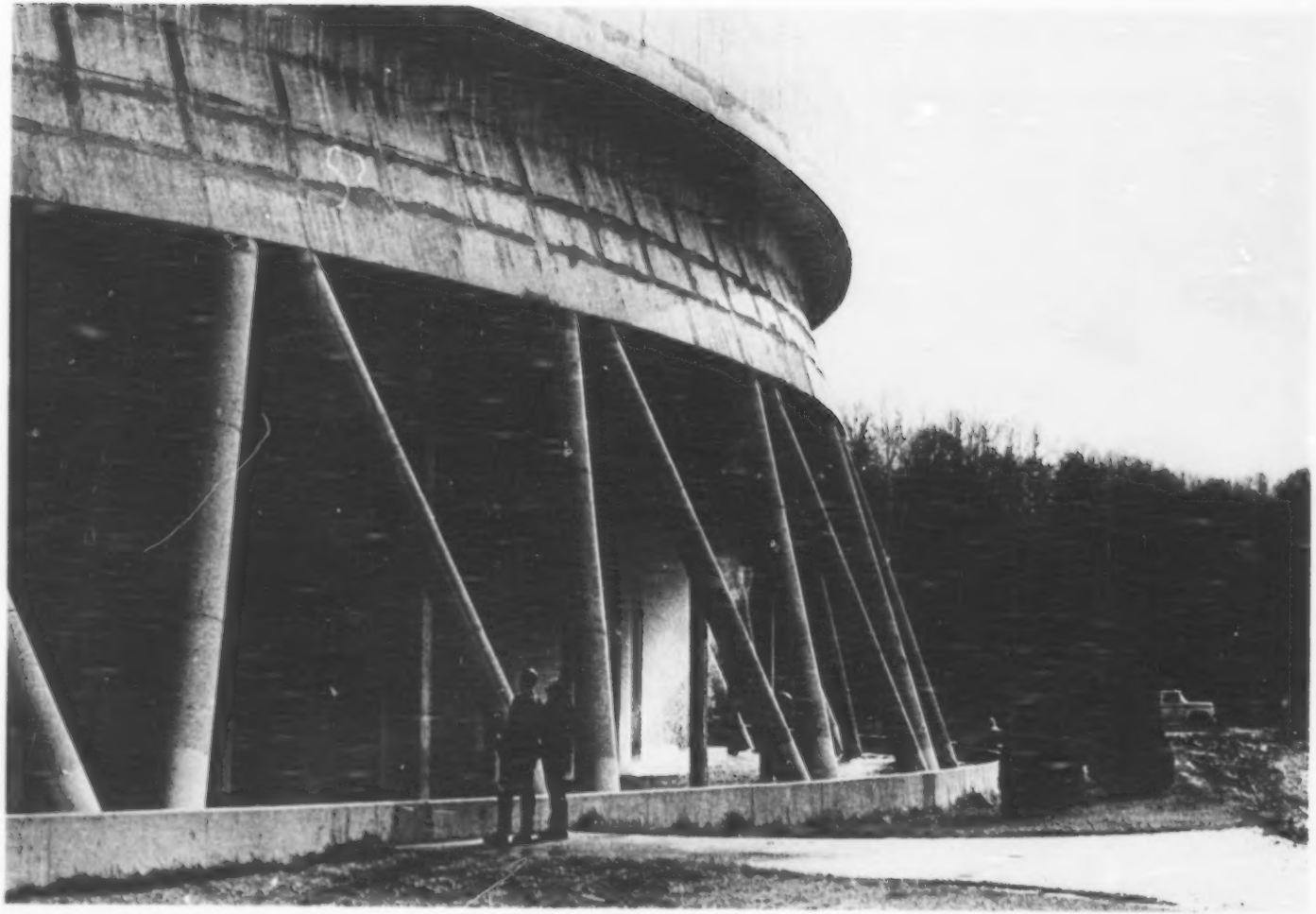

FIGURE 15. Air inlet with cooled water showering from the tower fill in the counter-flow, natural-draft cooling tower at the Big Sandy Powerplant, Louisa, Kentucky.

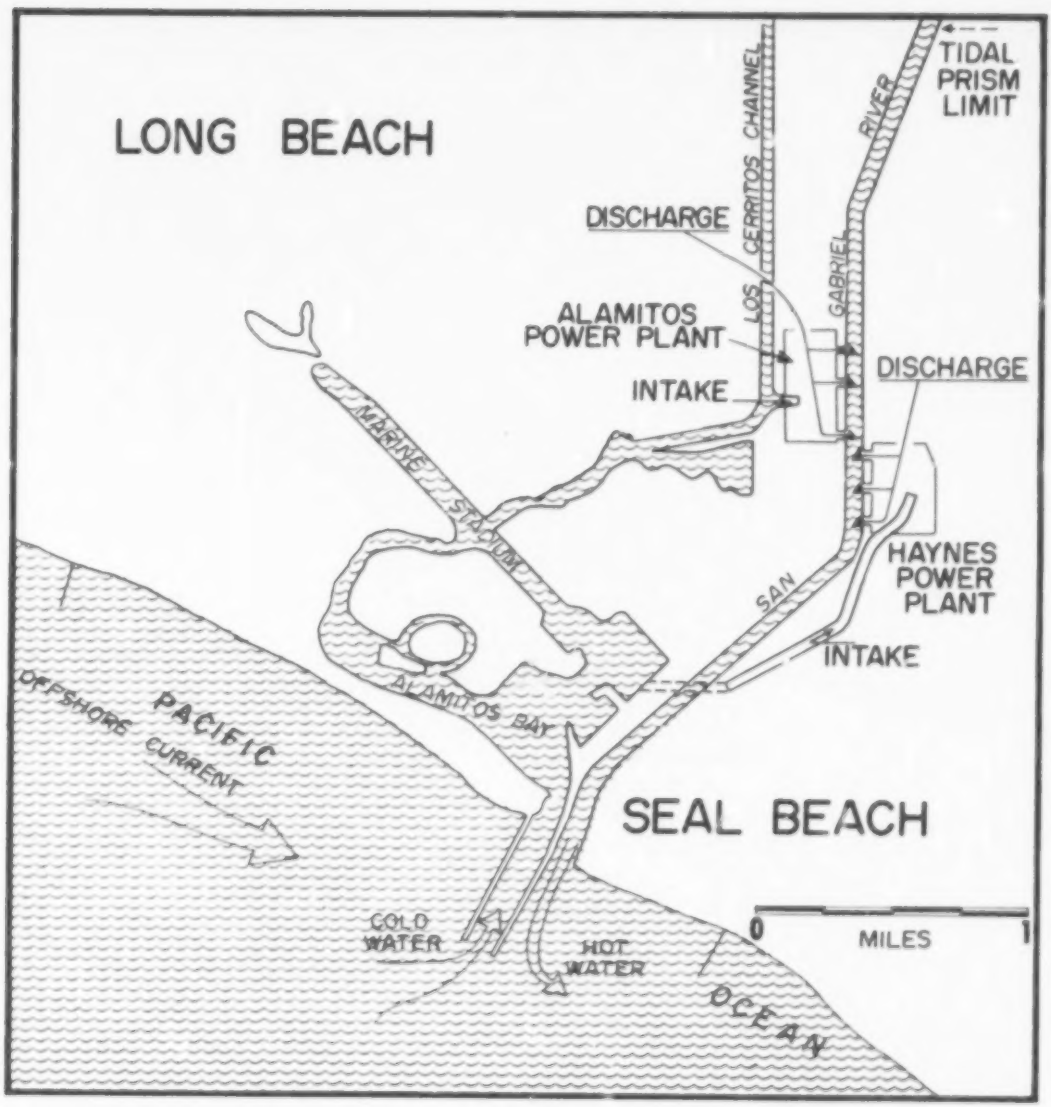

FIGURE 16. The 3,530,000-kw powerplant complex located on the southern California coast uses sea water for cooling with discharges into the tidal prism of the channelized San Gabriel River, which has insignificant natural flow under normal conditions.

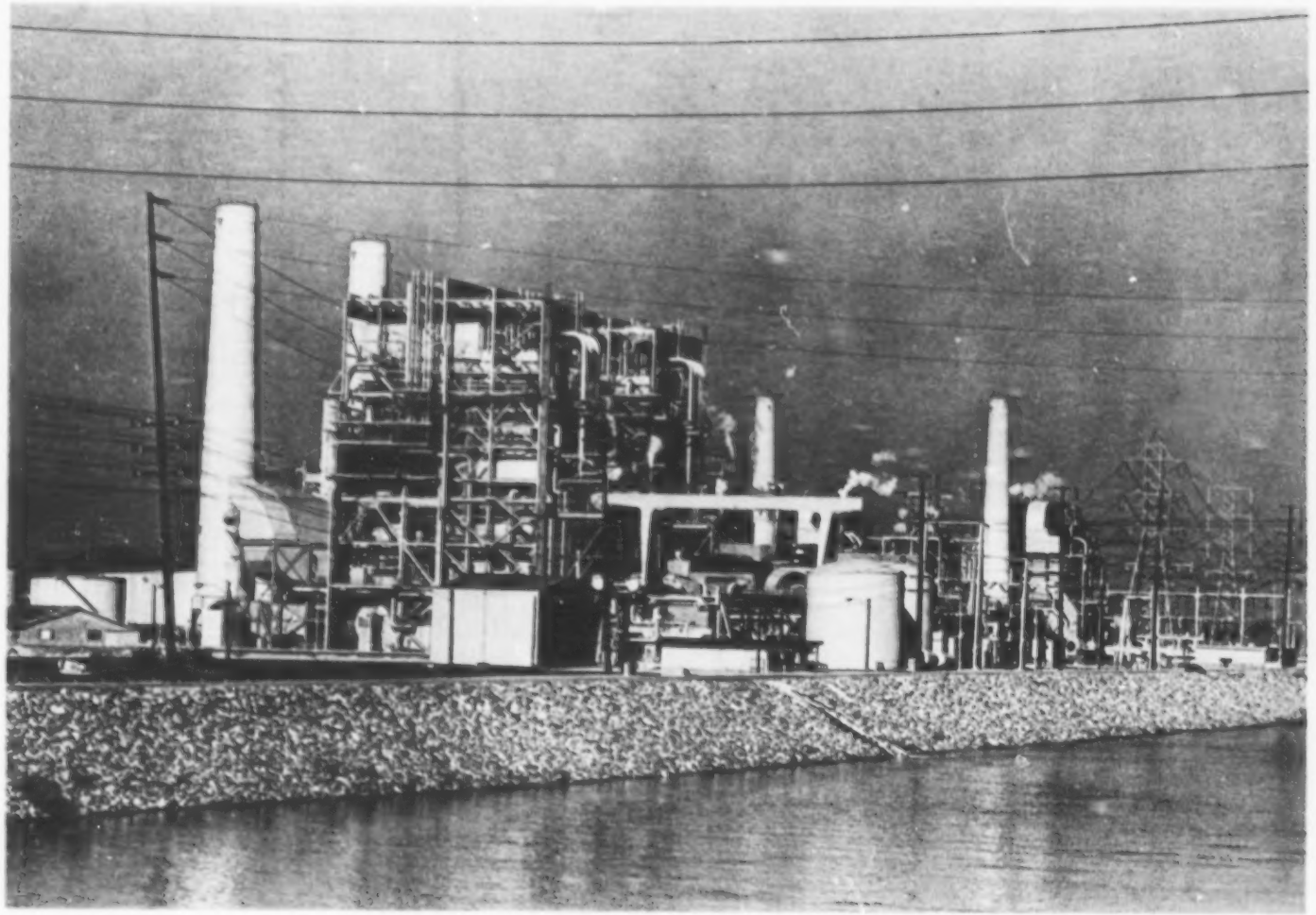

FIGURE 17. Alamitos Power Plant at Long Beach, California, uses sea water for cooling which is discharged into the "dead-end" tidal prism of the channelized San Gabriel River.

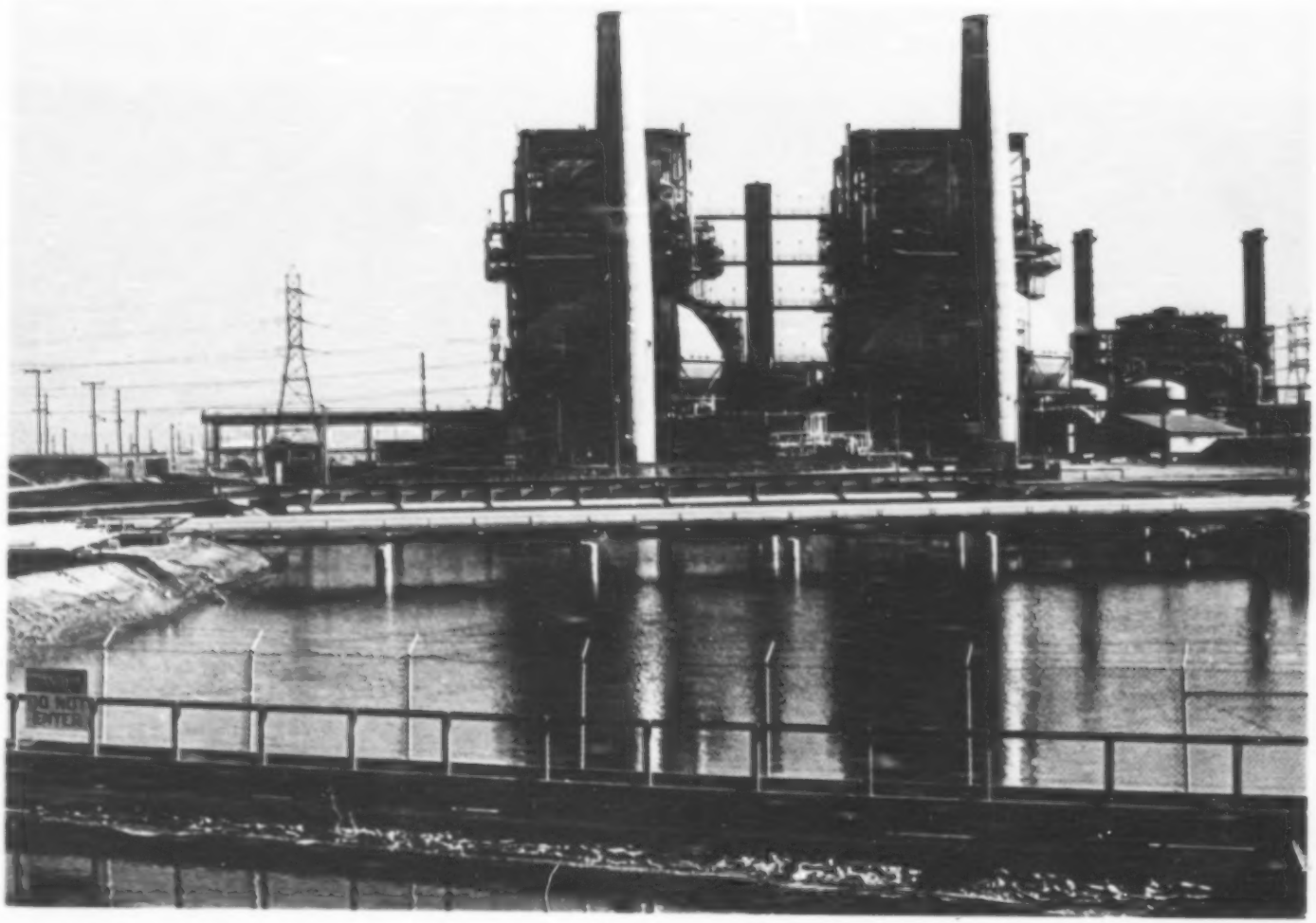

FIGURE 18. Intake channel which delivers sea water to Alamitos Powerplant, Long Beach, Calif. Accumulated litter has been carried from the Long Beach Marina on Alamitos Bay.

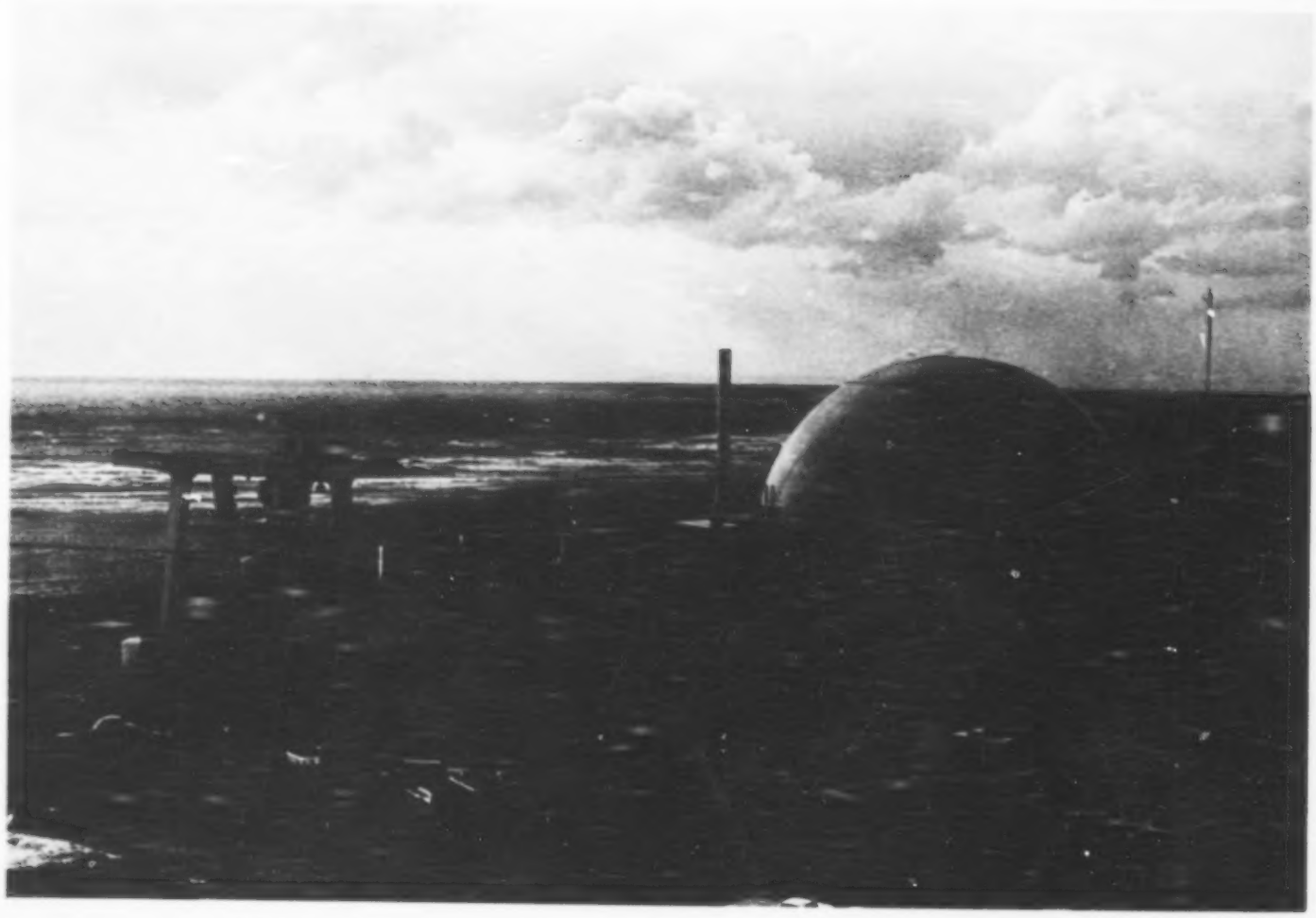

FIGURE 19. San Onofre Nuclear Powerplant about halfway between Los Angeles and San Diego. Sea water for cooling is pumped through intake and discharge lines extending offshore.

APPENDIX B

POWER PLANT DATA

APPENDIX B
POWER PLANT DATA

1. Name	Keystone Generating Station	Mt. Storm Mine-Mouth Power Station	Ft.Martin Power Station
2. Location	Near Shelocta, Pa., on Indiana-Armstrong Co. Line	On the Stony R. near Mt.Storm, W.Va.,in Grant Co.	On the Monongahela R. near Pt.Marion, Pa.
3. Owner (s)	Multiple (Investor-Owned Utilities	Virginia Elec. and Power Co.(VEPCO)	Alleghany Power System and Duquesne Light Co.
4. Dates in operation	1967 and 1968	1965 and 1966	1967 and 1968
5. Generating Capacity	1800 MW from 2 units	1080 MW from 2 units	1080 MW from 2 units
6. Turbine Steam Data (1)	3675/1000/1000	2520/1000/1000	3500/1000/1000
7. Fuel:			
a. Type	Coal (mine-mouth)	Coal (mine-mouth)	Coal (mine-mouth)
b. Sulfur (%)	2.4	--	--
c. Ash (%)	17	--	--
d. Supply (ton/day)	15,600	9600	8200 to 10,000
8. Condenser Cooling Water Req't.(gpm)	560,000	500,000	400,000 to 540,000
9. Waste Heat Treatment:			
a. Towers			
Number	4	--	2
Make	Hamon-Cottrell	--	Marley
Type	Hyperbolic (counter-current)	--	Hyperbolic (cross-flow)
Size (2) (feet)	325/247/142	--	370/373/--
Range (^{o}F)	28	--	17.5 to 24
b. Reservoir			
Location	--	Stony R.	--
Surf.Area(acres)	--	1200	--
Cooling Water Discharge	--	Shoreline	--
c. None			
Coolant	--	--	--
Discharge Location	--	--	--
10. Plant "Makeup Water" :			
a. Req't. (gpm)	8500 to 15,500	500,000	10,000
b. Source	Crooked Creek (3)	Reservoir	Monongahela R.
11. Chimneys(Stacks):			
a. Number	2	2	2
b. Height (feet)	800	350	550
12. Stack Emission Control	Electrostatic Precipitators	Fly ash storage silos	Electrostatic Precipitators

(1) pressure (psig) / temp.(^{o}F) / reheat temp (^{o}F)
(3) downstream of a 25,000 AF reservoir on North Branch of Plum Creek

Clinch River Plant	Big Sandy Plant	Alamitos Steam Station	San Onofre Nuclear Generating Station
Near Carbo,Va.,in Russell Co.	Near Louisa,Ky., on Big Sandy R.	Between Los Cerritos Channel & San Gabriel R., L. Beach, Calif.	4 miles SE of San Clemente Calif., within Camp Pendleton.
Appalachian Power Co. (American Elec.Power System)	Kentucky Power Co. (American Elec. Power System)	Southern Calif. Edison Co. (SCE)	SCE and San Diego G & E
1958 and 1961	1963 and 1969	1956-57; 1961-62; 1966	1968
700 MW from 3 units	265 MW from 1 unit (+800 MW in 1969)	1950 MW from 6 units	450 MW from 1 unit
2000/1050/--	2400/1050/1050	2180/1000/1000; 2560/1050/1000; 3599/1000/1000	680/500
Coal (mine-mouth)	Coal (mine-mouth)	Natural gas or oil	Nuclear
0.5 - 0.6	1.0	0.3 (oil)	--
15	15	0,004 (oil)	--
5300	2100 (+5500)	--	--
330,000	120,000 (+248,000)	144,000 + 270,000 +468,000 = 882,000	350,000
5	1 (+1)	--	--
Marley	Marley	--	--
Mechanical (induced draft	Hyperbolic	--	--
(4-10 cell; 1-14 cell)	320/245/140 (370/395/178)	--	--
19 to 20	--	--	--
--	--	--	--
--	--	--	--
--	--	--	--
--	--	Sea water	Sea water
--	--	San Gabriel R.	Outfall 2600 ft. offshore
7500	5000 (+5000)	882,000	350,000
Clinch R.	Big Sandy R.	Los Cerritos Chann.	Intake 3200 ft. offshore
2	1 (+1)	4	--
450	358 (826)	200	--
Multiclones	(4) Multiclone (Electrostatic Precipitator	None (Testing dolomite coated filter bags on one unit)	--

(2) height/diam. at base /diam. at top
(4) The new chimney and stack emission controls will replace the existing facilities